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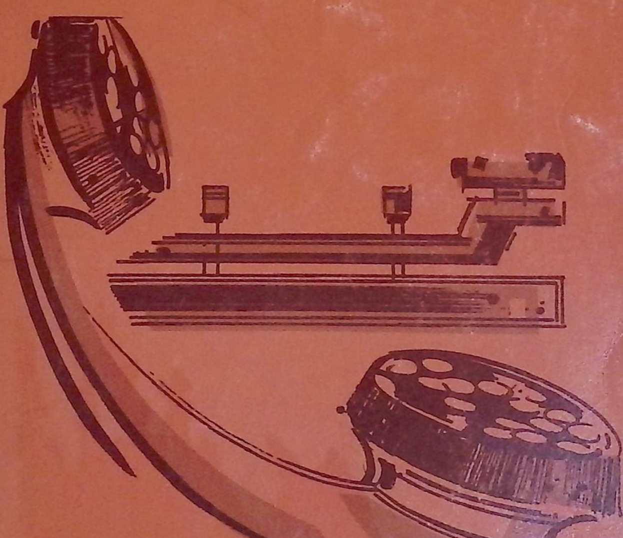
GENERAL CLASS Amateur License HANDBOOK

by HOWARD S. PYLE W7OE

Covers FCC license examination
for Technician, Conditional,
and General-Class license.



GENERAL CLASS

Amateur License Handbook

by Howard S. Pyle W7OE

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PREFACE

Many of the 250,000 licensed hams in the United States are operating on Novice tickets and must either qualify for a higher-class amateur license within two years or discontinue operation. In addition to those already licensed Novices there is an even greater number of individuals aspiring to enter the amateur ranks.

This book is directed primarily toward preparing the Novice for advancement to one of the higher-class licenses such as Technician, Conditional, or General; however, it is equally adaptable to the newcomer who wishes to bypass the Novice ticket and start right out at a higher grade.

The material in this book is comprehensive; yet it covers no more than is needed to pass the FCC examination. While mathematical formulas and theoretical discussions have been kept to a minimum, they are included to cover questions that may be asked and, where necessary, to provide a better understanding of the subject.

In addition to the material you'll need to pass the written exam, this book contains a helpful guide for learning and increasing your ability to use International Morse Code, on which you'll also be tested.

Questions and answers covering the material in the various chapters are also included. If you're able to answer the questions, work the simple problems, and have a basic knowledge of the circuits shown in this book, you should have no trouble passing the written portion of your FCC examination; your code ability, on the other hand, is strictly a matter of practice.

For those who *do* aspire to a career in electronics, one of the finest ways to acquire a solid foundation is through amateur radio. You need not have the brain of a physicist nor the skill of a master mechanic. You need only be an American citizen, or National, male or female, of average intelligence. Even age is unimportant, so long as you can pass the exam.

It is my sincere hope that this book will light the way to new and exciting experiences in ham radio by helping you qualify for one of the permanent grades of licenses.

HOWARD S. PYLE

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CHAPTER 1

LICENSE REQUIREMENTS

Several classes of amateur radio licenses are available, and contrary to popular belief a newcomer to the amateur ranks does not have to start with a Novice ticket.

Let's begin by elaborating on the various grades of licenses and the qualifications needed to obtain them. This will provide you with an understanding of the distinction between the grades. You can then intelligently prepare yourself for the one you choose and for which you are qualified.

AMATEUR EXTRA CLASS

The *Amateur Extra* is the highest grade ham license there is. It is, however, a prestige grade only, since it does not entitle the holder to any more privileges than a General ticket does. Since few readers will be eligible for the *Extra*-class license, we will ignore it in the following pages, except to say that you must (1) have held an amateur license of any class except Novice or Technician for at least two years since 1934, (2) have a comprehensive grasp of electrical and radio principles, and (3) be able to send and receive 20 words per minute or better in code to qualify. The only persons exempted from taking the examination are those relatively few hams who have held an amateur license prior to May 1917.

THE GENERAL CLASS

Your goal will undoubtedly be the General class, since you can enjoy nearly every privilege granted by the Federal Communications Commission to radio amateurs. Set your sights on the Extra class if you desire; but for the present, you should concentrate on making the grade as a General.

As a Novice you were required to send and receive a mere five words per minute in code and to pass a written examination covering only the most elementary electrical and radio principles, such as Ohm's law, the difference between current and voltage, rectifier and filter systems, etc. In addition you had to demonstrate, through the same written examination, that you knew enough about the adjustment of simple transmitters to assure legal operation. Add a few questions covering the pertinent portions of the Federal Communications Commission rules and regulations, and that was it. Moreover, the Novice license is only good for two years and is not renewable. The General license, however, is renewable every five years without re-examination.

In aspiring to the General class, your knowledge must be considerably more comprehensive and your code speed must have increased substantially. Both the written and the code tests for a General license must be taken before an FCC engineer. The greater knowledge required for you to pass the General exam is logical. Two years as a Novice is ample time for you, in your spare time, to master the higher code speed and more advanced theory of electricity and radio. Going up the amateur ranks is like attending high school. As a freshman you were given one year to qualify for sophomore, another as a junior, and still another as a senior. You could say your Novice years were your freshman and sophomore years. Following the same analogy, the Technician is a junior and the General a senior. Unlike high school, though, you can skip directly from freshman to senior if you can qualify!

Whether you are an adolescent or an adult, it will pay you to establish regular study hours and stick to them. Maybe half an hour each evening is all you can squeeze in, or perhaps an hour or so every other day. Sometimes you will be able to work in a few extra hours on an otherwise dull weekend. At least acquire a study *habit*. Don't expect to get anywhere by devoting a half hour this week, maybe three hours two weeks hence, and then dropping your studies until a more convenient time or until the urge moves you. Such hit-or-miss tactics will get you nowhere fast! Even worse, much of what you learned will probably slip away from you by the time the next session rolls around. It's more *fun* if you're methodical, and your progress will be most gratifying.

Before passing on to the other grades, let's give you a few more pointers about the General license. Any American citizen or national is eligible to take the examination. It makes no difference whether or not the applicant has ever had a radio operator's license, either amateur or commercial. However, anyone who holds a commercial radio*telegraph* license or has held one within the past five years does not have to take the code test. This is the *only* exemption that can be claimed on the General examination, and those entitled to it must submit proof.

The General examination *must* be taken in person at one of the twenty-four FCC district offices or at one of the examining points set up periodically. Amateur examinations are conducted on various days of the week and at various times of the day; to save yourself a needless trip, it is best to write or call the district office where you intend to take the examination to find out the exact date and time. Also request Application Form 610; you can save time by preparing it in advance and presenting it to the examining FCC engineer when you appear. Fill this form out completely; also have it notarized if you are applying for a station license (included on same form). Notarization is not required.

While the privileges extended to the General and Conditional classes are of much broader scope than those for the Novice class, certain frequency segment reservations are reserved for holders of the Extra and/or Advanced class of license. The bands of frequencies allotted for amateur operation between 3500 kc and 148 mc are given in Table 1-1. The type of operation and the class of license needed to operate on each frequency are also given. Limited operation is allowed between 1800 and 2000 kc for General, Advanced and Extra-class licensees and several bands above 220 mc are available to all except Novice licensees. The privilege for the Conditional license are the same as for the General class.

THE CONDITIONAL LICENSE

The requirements for Conditional and General licenses are the same. The only difference is that the Conditional examination is taken by mail rather than in person before an FCC examiner. To be eligible for a Conditional license (assuming you otherwise qualify), you must satisfy one or more of the following conditions:

1. Live more than 175 air miles from the nearest point where the FCC conducts examinations at intervals of not more than six months. Your proposed station also must be outside this 175-mile radius.
2. Be in military service, the nature of which prohibits you from appearing in person. You must submit a letter from your Commanding Officer attesting to this.
3. Have a physical disability which prohibits such travel. This must be attested to by a signed statement from your physician.

Table 1-1 Amateur Frequencies

Frequency Band	Operation		Class of License*				
	CW	Phone	N	T	G	A	E
Kilocycles							
3500—3525	X						X
3525—3700	X				X	X	X
3700—3750	X		X		X	X	X
3750—3800	X				X	X	X
3800—3825	X	X					X
3825—3900	X	X				X	X
3900—4000	X	X			X	X	X
7000—7025	X						X
7025—7150	X				X	X	X
7150—7200	X		X		X	X	X
7200—7250	X	X				X	X
7250—7300	X	X			X	X	X
14,000—14,025	X						X
14,025—14,200	X				X	X	X
14,200—14,275	X	X				X	X
14,275—14,350	X	X			X	X	X
21,000—21,025	X						X
21,025—21,100	X				X	X	X
21,100—21,250	X		X		X	X	X
21,250—21,275	X	X					X
21,275—21,350	X	X				X	X
21,350—21,450	X	X			X	X	X
28,000—28,500	X				X	X	X
28,500—29,700	X	X			X	X	X
Megacycles							
50.0—50.1	X					X	X
50.1—54.0	X	X		X	X	X	X
144.0—147.9	X	X			X	X	X
145.0—147.0	X		X				
145.0—147.0	X	X		X			
147.9—148	X				X	X	X

*N = Novice, T = Technician, G = General, A = Advanced, E = Extra

4. Have sufficient evidence that your temporary residence is for a continuous period of at least 12 months outside the limits of the United States, its territories, or possessions.

The procedure for conducting the Conditional examination is essentially the same as for Novice or Technician. When you are ready, select your volunteer examiner. He (or she) may be anyone 21 years of age or older who holds either a General, Advanced, or Extra-Class license. In addition, the holder of a valid commercial radio*telegraph* license or some one employed as a U.S. Government radiotelegraph operator, at a manually-operated radiotelegraph station may give the test.

You no doubt know an amateur or professional operator who is willing to act as an examiner. If not, a local ham radio club can probably suggest one. You can ask the nearest FCC field office for the name of an amateur in your vicinity who has expressed willingness to examine applicants for amateur radio operator licenses. If neither of these approaches is practical, write the American Radio Relay League, Inc., 225 Main Street, Newington, Conn., for information. Examiners serve in a voluntary capacity; they receive no compensation and, in fact, would violate federal radio statutes should they accept such. Therefore you cannot *demand* that they serve; all you can do is *request*. Be courteous and keep in mind that they are doing you a favor. You will find few who will refuse.

When you have arranged for an examiner, write the FCC at Gettysburg, Pennsylvania 17325, and request application form 610. Fill the application out completely (your examiner can assist you if you are uncertain about some entries) and then have your examiner administer the radio code test to you.

After you complete the form and pass your code test, have your examiner write a letter to FCC at Gettysburg requesting the appropriate examination papers. This request should contain the following information: (1) the names and permanent addresses of both the examiner and the applicant; (2) a description of the examiner's qualifications to administer the examination; (3) the examiner's statement that the applicant has passed the code test for the class of license involved within the ten days preceding the examination; and (4) the examiner's written signature. Note that a period of only *ten* days after taking the code test is permitted in which to forward the application and the filing fee (if required).

When the request is received from the examiner, the FCC will forward the examination papers to him and he will notify you of their receipt. Make an appointment to appear before him to take the examination. Conduct of the examination follows a prescribed pattern described on the sealed envelope sent to your examiner. He will open the envelope and hand you the appropriate papers. You may then proceed in accordance with the "Instructions to the Applicant," printed on the face of the envelope. Upon completion, hand all papers to your examiner and complete Part I on the reverse side of the answer sheet, if applicable. The examiner will then complete Part II of this form and attach it to *all* of the examination papers. He then places all of the papers in the stamped envelope which you have supplied to him and mails them to FCC in Gettysburg, Pennsylvania within the time prescribed. The answer sheet must not be folded, stapled, or multilated; therefore, the envelope which you supply the examiner should be no less than 9″ × 12″, should contain a protective piece of stiff cardboard, and should be prominently labeled on the outside face, "DO NOT BEND OR FOLD." First-class mail should be used; air mail is of no advantage in returning these papers to FCC as they are interested only in the postmark showing the date of mailing.

Passing speed for the Conditional examination is the same as that for the General class—13 words per minute in the International (Continental) radiotelegraph code. Your code examiner has a choice of material which he sends or asks you to transmit. Generally, it should comprise mixed letters, words, and figures, occasionally interspersed with punctuation. It should contain each letter of the alphabet at least once and all of the figures from 1 through 0. It is wise to develop a speed of 15 words per minute (or more) before taking the examination. A certain amount of nervous tension is inevitable during the test. The knowledge that you have been consistently copying more words per minute than the test calls for, will boost your confidence and enhance your chance of passing.

After you have passed your code test, the examiner will proceed as outlined in previous paragraphs. However, should you *fail* to pass, no further action is required on the part of the examiner or yourself. He shall not request written examination papers from FCC, nor will you send in your application; hold it for your next attempt. A waiting period of thirty days is currently prescribed before you can initiate action to again take the code test; if successful this time, send in your application and the examiner's request for the written examination as previously described. You may repeat this procedure every 30 days without limit until you pass the code test.

From then on, it is a matter of waiting. Within a few days you may receive a post card notice from FCC stating whether or not you passed your examination. However, the actual license must be in your possession before you begin operating. Usually you must wait from six to eight weeks before receiving the formal license. *Do not write* the FCC to inquire when you may expect receipt. Waiting is often tough but you will delay rather than expedite the processing if you make such inquiries. More than about eight weeks delay in receipt, however, may warrant a brief post card inquiry. It is always possible that your mailing may have gone astray. You need merely tell them that you "filed application for amateur radio license, accompanied by examination papers and filing fee (when required) and same was mailed from .... (your town) .... on .... (date)"

Meanwhile, if you hold a valid Novice or Technician license, you can continue to operate your Novice or Technician station but only under the limitations imposed by the class of license you hold. Also, should you use another amateur station in either of these categories, you must use *his* call letters—not yours. Many amateurs are of the mistaken impression that call letters are assigned to individuals; they are not. They apply only to the specific station, either fixed, portable, or mobile. In other words, *you* are not "WA6XXX"—your equipment is!

THE TECHNICIAN CLASS

The written examination for the Technician-class license is exactly the same as for the General and Conditional classes. Moreover, this examination is taken by mail and the procedure is identical except that the code-speed requirement for Technician is only 5 words a minute, rather than the 13 wpm required for both the General and Conditional classes. However, Technicians are denied the full amateur privileges inasmuch as they cannot operate on frequencies below 50 megacycles. The Technician classification is of interest to those amateurs who are experimentally minded and have only a mild interest in the type of communication indulged in by the Conditional, General, and Extra licensees. Since most of the Technicians activities are carried on by radiotelephone, the need for a code speed beyond 5 words per minute is seldom necessary.

Despite its limitations, the Technician class does serve a useful purpose. It encourages those who like to do experimental work but might not be able to get a license if the code requirements were too strict. Since code speed is the only difference between a Technician and higher-grade license, a Technician who desires to become a General and enjoy expanded privileges may do so quite easily. All he has to do is build up his code speed to 13 words per minute and take basically the same written examination. He will have to appear at a regular FCC examination point, of course, unless he qualifies for a Conditional license. If so, he will be re-examined by mail and given the code test.

LICENSE FEES

In 1964 a schedule of license fees for all radio services except civilian government and military services was put into effect by the FCC. This fee must be submitted with your application for station license. If application is by mail, it should be in the form of a check or money order made payable to the Federal Communications Commission. The fee is charged regardless of the disposition of the application; however, if the application is returned for additional information, no additional fee is required.

For all initial licenses, including new class of operator license and renewal of licenses, the fee is $4.00. The fee for modification of a license without renewal is $3.00. If the license is renewed and a modification is made, the fee is $4.00. In certain instances (specified in §97.51 of FCC Rules and Regulations) a specific call sign may be requested. When a specific call sign is requested, the fee is $25.00. This $25.00 fee does not apply if request is for a call sign previously held by you and application for renewal is made within one year after the expiration date of the license.

The only amateur licenses exempt from fees are: (1) Novice licenses, (2) stations for recreation under military auspices, (3) stations in the Radio Amateur Civil Emergency Service, and (4) informal applications for special temporary authority.

CHAPTER 2

THE RADIOTELEGRAPH CODE

If you now hold a Novice license you have undoubtedly enjoyed a few weeks or months of actual on-the-air communication. Lately, though, you've been giving serious thought to qualifying for a higher grade of license: Technician, General, or Conditional. In the Novice class, you can use radiotelegraphy in only small segments of just a few of the bands available to higher-grade amateurs. Another restriction is in not being allowed to use a variable-frequency oscillator (more commonly known as a VFO). You are necessarily "rockbound," meaning your transmitter must be crystal-controlled. How much more fun you would have as an all-round amateur, enjoying much broader privileges! You can after you pass the General or Conditional examination.

Perhaps you now hold a Technician license, but feel frustrated at being confined to the higher frequencies. There is nothing to deny you increased privileges other than building up your code speed and taking another written examination.

Maybe you're inclined to scoff at becoming a Novice; you want to go right after the General or Conditional license. You can, of course. But you're setting yourself a rather stiff goal if you have had no experience in the radiotelegraph code and little, if any, technical knowledge. It's more fun to enter the ham ranks as many other thousands have done—through the Novice gateway. The written examination is extremely simple, and anyone can meet the code-speed requirement after a few weeks of spare-time study and practice. If you have the technical knowledge but code is your problem, you might start with the Technician license.

If you have ever held an amateur license of any kind, you're ineligible for a Novice license. Still you are bound to remember most of the code and the basic electrical and radio principles, even though your code speed may have deteriorated over the years. After a few evenings and weekends with a code-practice oscillator and a good ham manual, you'll be amazed at how little you've forgotten.

Let's talk about the fellow who has been a commercial radio operator and maybe still is. Whether he has worked only radiotelephone or has been a seagoing or shore-station operator with a radio*telegraph* license makes little difference. The phone man will either have to learn the code, or else brush up on it. The radiotelegrapher has one advantage—he can already copy 13 words a minute, and then some, in his sleep! *Both* know more about the technical aspects of radio than any ham license requires. If you belong in either category, you are right next door to being a ham.

LEARNING THE CODE

What about those who have never held an amateur license, don't know the code, and have only a smattering of technical knowledge, but want to skip the Novice class and go directly to General? Their best bet, before going any further, is to pick up a good book devoted to preparing the reader for the Novice class. Such a book should cover learning the code and building up speed. It should also cover electrical and radio theory. After making sure they know the fundamentals and can send and receive more than 13 words a minute, they will be able to bypass the Novice grade and go directly to General. It will probably take them longer than if they had taken to the air as a Novice and gained the practical experience which goes with it.

For the old-timer who was a ham but dropped it many long years ago, we suggest the same exposure to the code and theory. The speed with which the "dits and dahs" will return to him will be a revelation. This manual will give him all he needs for the General-class examination. Ham magazines and other handbooks are recommended reading also. Since his former license makes him ineligible to become a Novice and go on the air, he'll have to find other ways to build up his code speed.

It is presumed, however, that you are a Novice, and that you are reading this book because you want to go for the General, Conditional, or Technician license. You'll have to build up your code speed, unless you've been on the air long enough and have had sufficient contacts so that you were able to reach the required speed. Few do in this manner—even the youngsters who live with the code during most of the day and dream about it at night! Those who don't have that kind of time will have to set up regular study periods. As mentioned in the previous chapter, methodical study habits are a must. Doing it helter-skelter won't be of much help.

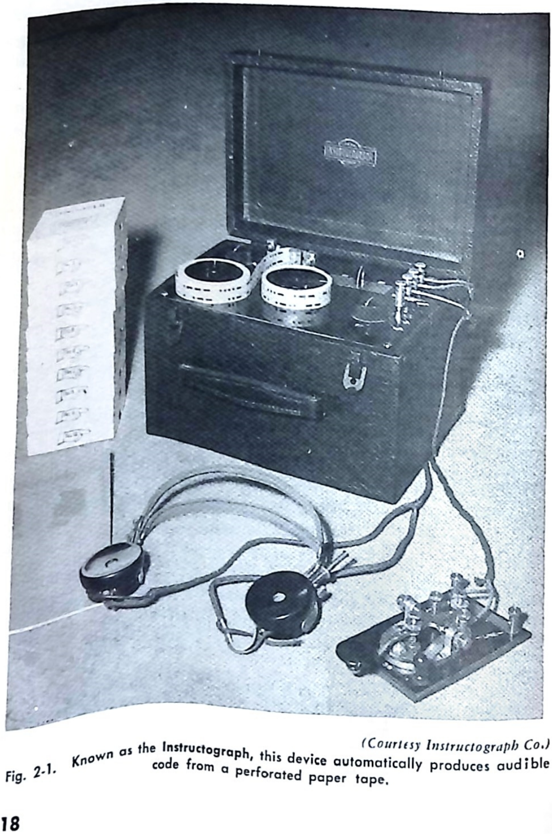
Once having decided to increase your code speed, you'll want to know how you can accomplish this. Many of you are going to pose the old thread-bare question: "Why must I learn the radiotelegraph code when I only want to be a radio*telephone* amateur?" Simply accept the fact that proficiency in the radiotelegraph code at a minimum speed of 13 words per minute for the General and Conditional licenses is a must. The reasons for the code requirements are sound, and you might just as well resign yourself to accepting them; they are essential to procurement of a ham license and probably will be for some time to come. So, the Novice or Technician who has already qualified in code at the extremely slow speed of 5 wpm may chafe at the bit to some extent, and the fellow with no background in code may adopt an indignant attitude when told that he *must* have sufficient code ability to qualify for the license he wants. But you can't beat it; it's the law and it's a *must!* Accept it and devote your energy to increasing your speed to meet the requirements for the license you want.

There are many ways to acquire the advanced speed necessary for a higher-grade license. Suppose we analyze the various methods.

MECHANICAL CODE TRANSMITTERS

As a teacher of the radiotelegraph code for many years, the author prefers one of the mechanical devices which, under control of the user, will produce perfect code by the hour at various speeds. There are several reasons for such preference: the character formation is perfect; each dot, dash and space are of identical proper length; characters are crisp and snappy; and no interference of any kind is present. Any slight room noise which you may experience is easily over-ridden by adjustment of volume and/or tone of the oscillator output. Buzzers are not recommended for use with these machines—they are prone to change tone frequently and the volume is low and not adjustable. If you can afford to buy or rent a mechanical transmitter, you can afford the small additional cost of an audio oscillator. You may wish to build one from a kit, or even from scratch, and thereby save yourself a few dollars.

There are several types of automatic transmitters. All accomplish the same purpose and all produce perfect code transmission. Some make use of a perforated paper tape; one uses a method whereby the code characters are cut on a copper wire drawn to an inverted "V" shape and wrapped around a steel drum. An earlier type used a stamped aluminum disc with the code characters projecting around the circumference; however, to the best of our knowledge, these are no longer manufactured, but may occasionally be found on the second-hand market. Recent automatic code transmitting devices make use of phonograph records; others use the tapes of the conventional tape recorders with which you are no doubt familiar. All of these devices will satisfactorily transmit the characters of the International radiotele-



(Courtesy Instructograph Co.)

Fig. 2-1. Known as the Instructograph, this device automatically produces audible code from a perforated paper tape.

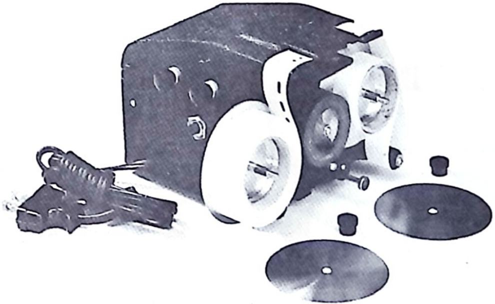
graph code and are fine for practice purposes. If you feel that one of these "mechanical operators" will be the best answer, consult the advertising pages of electronic and ham magazines and write the manufacturers of such equipment for full information and prices. In the larger metropolitan areas you will often find machines of this type for sale or rental at amateur radio supply houses.

Let's now examine them individually.

Paper-Tape Code Practice Machines

These devices make use of a paper tape about one-half inch wide and about as long as a typewriter ribbon. Ordinarily they are wound on a spool which is similar to that of a typewriter. Most of these machines are activated by a built-in variable-speed electric motor, although a few have a clock-work mechanism, also variable, as the driving source. Fig. 2-1 shows one type of automatic code transmitter that employs paper tape. As the tape—pre-punched by the manufacturer—progresses, it unwinds from the "full" spool and is taken up by an "empty" spool at a constant and controllable speed. In making its journey from the full to the empty spool it passes through a pair of contact fingers which produce the audible letters, numerals, and punctuation that have been pre-cut in the tape.

Speed of transmission is determined not only by the motor speed, but also through selection of the various tapes which are supplied with such machines. Some tapes have characters occurring at greater intervals than others; the length of each charac-



(Courtesy Gardiner Co.)

Fig. 2-2. Another type of automatic code practice device that employs paper tape.

ter, while still preserving the proper ratio of dots, dashes and spaces, will be greater. These are the "slow speed" tapes but they are adjustable, within reasonable limits, by varying the speed of the driving motor. Fig. 2-2 shows another type of automatic code transmitter using perforated paper tape.

Some of these paper-tape code-transmitting devices include a built-in audio oscillator and require no external items for use. They are completely self-contained, including a loud speaker as well as terminals for headphones. Most of them also include terminals to which a sending key of the hand or of the semi-automatic type may be connected, and the machine then serves as a means of practicing code transmission in addition to its primary purpose in providing code-receiving practice.

Metallic Wire Machines

As this book is written, we know of only one machine which uses a metal wire. The metallic wire is best described as a wire which has been drawn into an inverted "V" shape. Code characters are then cut into the wire so that when it passes through the contact mechanism, the circuit to the loud speaker or headphones is made and broken according to the character cuts. A steel drum serves to handle the progress of the wire as it moves from start to finish. Speed control is readily accomplished by the user as in the paper-tape machines previously described.

Recording Tape

Most people are familiar with the conventional tape recorders whereby recordings can be made, then played back. If you have access to such a recording device, you may buy pre-recorded tapes which contain lessons in the radiotelegraph code at various speeds. These are available from several manufacturers and may be had to fit your recorder. If the budget is a bit tight but you have a communications receiver and an extra tape, you can record your own code practice material from one of the periodic code practice sessions conducted by W1AW.

Phonograph Records

A number of manufacturers offer conventional phonograph records designed to provide radiotelegraph code practice at varying speeds. Some of these are complete courses in which the speed of transmission is gradually increased from record to record. As with the steel recording tapes, the instructor frequently and briefly identifies the various characters transmitted and makes pertinent helpful comment. Such records may be purchased in phonograph stores or ordered from advertising in the electronic and radio amateur periodicals.

BUILDING UP YOUR CODE SPEED

Lacking access to a mechanical device, you are by no means denied a method for building up your code speed. There are many other ways in which you can attain this objective. These include copying the scheduled radio transmission of amateur code-practice stations, those of other amateur stations in the higher grade license brackets, working "two-way" with other Novice stations and, when the opportunity presents, those of General status. You can also progress in your code speed if you are acquainted with a friendly amateur with a good "fist" (meaning that he is a good sender) who will send to you, using a buzzer or audio oscillator right in your own home or his, at frequent intervals. Suppose we discuss these methods a little more in detail in the following paragraphs.

Second to the automatic transmitters previously described, the code-practice transmissions conducted by a considerable number of amateur stations is recommended. These all operate on definitely scheduled times and frequencies, and a number of the more prominent of these stations use automatic transmitters for perfect character formation and constant speed. Their actual speed of transmission is not under control of the receiving operator, but is varied at the transmitter. Transmissions generally start at a speed of 5 words per minute and ordinarily continue for a 10-minute period. After appropriate announcement, speed is increased to 7 or 8 words per minute for a like period, then to 10, 13, 15, etc., on up to as fast as 40 words per minute! As mentioned previously, the most consistent code-practice station for the eastern half of the United States is the headquarters station of the American Radio Relay League, W1AW, at Newington, Connecticut. Its transmissions may be found nightly at 9:30 P.M. EST on 3555, 7080 and 14,100 kilocycles as well as on several of the higher frequency bands; transmission is simultaneous on all frequencies. A more complete schedule may be had on request by writing the League at 225 Main Street, Newington, Connecticut 06111.

Many code-practice transmissions are made by various radio clubs as well as by numerous individual radio amateurs scattered throughout the country, all on a voluntary basis. Information about these transmissions frequently appears in the columns of QST, the official monthly publication of the American Radio Relay League, Inc., or a letter to the League will generally bring a reply listing several such stations which you may expect to hear in your general area.

While most of these stations employ relatively high power, it must be remembered that their signals heard through the medium of your radio receiver, may be subject to interference which will make it difficult for you to copy at times. The average experienced amateur who is familiar with these code-practice programs generally respects them and refrains from interfering transmissions. Nevertheless, you may experience some QRM. In one way, it is of some advantage. In two-way communication with other amateurs you will often experience such interference, as well as that from atmospheric disturbances and man-made electrical and electronic devices. To be a competent amateur radiotelegrapher, you must—and will—develop the ability to concentrate on the radio signal which you want to hear and ignore all other audible sounds. When you have accomplished that at a speed of about 15 to 17 or 18 wpm, you need not fear the General or Conditional license code test which will come to you completely interference-free.

Face-To-Face Code Practice

We call this "face-to-face," although the more common amateur expression is "eye-ball," both meaning that two amateurs are within sight and conversational sound of each other without benefit of any equipment whatsoever: no telephone, radio transmitter or other device. Frankly, the author prefers "face-to-face," as the term "eye-ball" seems on the grisly side! The feminine members of the ham fraternity handle this much more delicately by referring to such conversational interchanges as "eye-lash." Be that as it may, face-to-face code practice means that you have been fortunate in securing the services of an experienced ham with a good "fist" to send you code. While his sending will probably not be the crisp, precise character formation of an automatic machine, it will be the type to which you will listen and interpret in your actual on-the-air contacts. Whether he uses a semi-automatic key, commonly referred to as a "bug," an electronic keying device or the old reliable "hand key" is of small consequence, provided he is competent to produce good readable code. A typical bench setup for group code practice is shown in Fig. 2-3.

A half hour of such practice broken into 2 or 3 10- or 15-minute intervals is enough at one session; more than that becomes tiresome and boring. It is better to vary such sessions with study of the technical requirements for the examination. Make code-practice periods as frequent as you can, perhaps every evening if your other activities permit, or maybe you can work in several sessions on a weekend—the more practice you get, the quicker you'll qualify. Another excellent method of acquiring greater code speed is by attending a school devoted to teaching

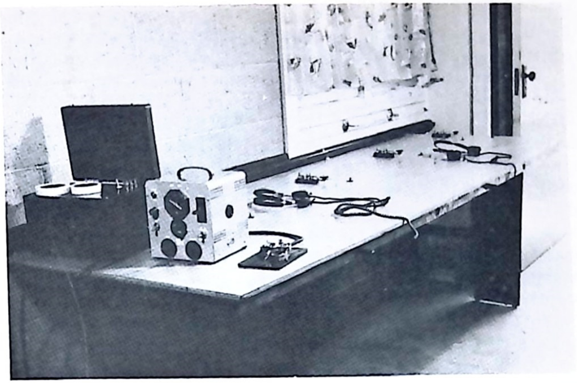


Fig. 2-3. Typical equipment setup for group code instruction.

the international telegraph code. A typical code session is shown in Fig. 2-4.

Aside from the regularly scheduled code-practice transmissions of the stations, which we previously referred to, you can use random code transmissions on the amateur bands as a method to improve your receiving speed. Actually, this is not too good;

(Courtesy Massachusetts Radio and Telegraph Schools.)

Fig. 2-4. Class instruction at schools devoted to teaching the International radiotelegraph code is an excellent way to acquire greater code speed.

most of such communication is greatly abbreviated and will handicap you considerably unless you are familiar with the contractions. A modified form of "Phillip's Code" is soon adopted by an amateur after his receipt of his initial license, and you will hear something like this: "OK OM UR SIGS HR RST569 RUNNING 40 W HR TO HALF WAVE DOUBLET." It makes sense to the fellow he is talking with but at the same time makes poor code practice. Also, just as you feel that you are beginning to copy some station solid, he signs over to the other station who may not even be audible to you. You will get a certain measure of help in this way if it is your only out, but it will fall short of being good code practice. You'll do a lot better if you can find a commercial station sending "press," as news dispatches are known telegraphically, provided such transmission is within your copying ability at least in part. These stations are relatively rare in the slower speed classification, but they do exist; the ordinary press transmission is usually accomplished at high speed by automatic transmission and is well beyond human aural interpretation.

"On-The-Air" Code Practice

On the air code practice is not a bad method if relatively competent operators participate. They need not necessarily be fast. Novice operators can satisfactorily work together in this manner, provided both are capable of fairly good character formation. Unfortunately, many Novices, while they have managed to pass their code examination at 5 words per minute are rather shaky during their first few weeks in actual on-the-air communication, and their character formation is somewhat difficult to interpret. If you are fortunate in having a good sender to listen to, you will make progress in building up your code speed, although it will be slower than one of the methods previously described. Should you make contact with a more experienced amateur of the General class who has acquired a greater sending competence through continued operation, by all means work him; you will find his transmissions much more readable. You'll be surprised, incidentally, at the number of General-class amateurs who will willingly adjust their transmitters to one of the Novice bands and lend a helping hand in assisting the newcomer to improve his sending as well as his receiving ability.

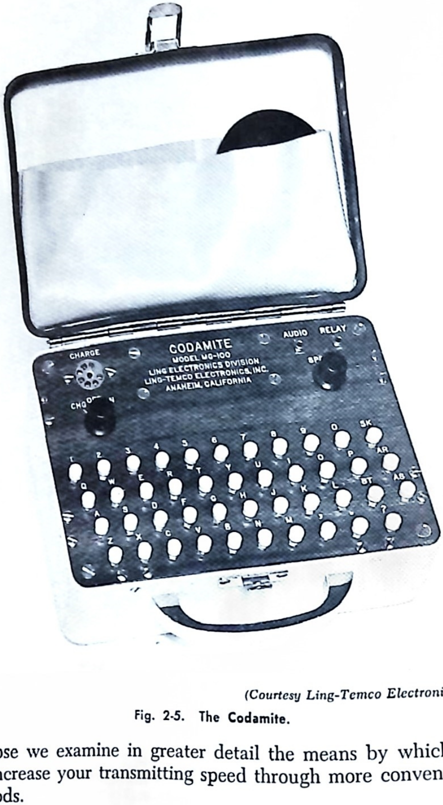
INCREASING YOUR SENDING ABILITY

So far we have considered only methods whereby you can increase the speed at which you can *receive* the radiotelegraph code and interpret it into intelligible letters, words, sentences and phrases. This, though, constitutes pretty much of a one-way track. As a radio ham you are going to have to acquire sufficient skill to *send* radiotelegraph code at a speed roughly equal to your receiving ability. Remember that *receiving* the code at the required speed is only half of the examination which you will be required to take to qualify for your amateur radio license.

There are no automatic mechanical aids which will be of service to you in learning to send faster. Naturally, we do not consider any form of telegraph key, whether it be the simple hand type, the semi-automatic "bug" or the electronic keyer, as an "automatic" aid to acquiring greater sending speed. They all require manual operation and a knowledge of the radiotelegraph code by the user—in this case, *you!* Most certainly there are completely automatic transmitting devices which require no knowledge of code, but they require manual manipulation by a human being. One such device is the teletypewriter which, in recent years, has acquired some measure of popularity among the more experienced hams who are experimentally inclined. These machines not only transmit intelligence, but they are also capable of receiving and printing it in conventional letters, numerals and punctuation on a paper tape or, in later models, on a sheet of paper! They do not, however, transmit the characters of the radiotelegraph code but use a 5-symbol arrangement of their own which may be received and interpreted only by a duplicate machine.

A recent innovation in automatic code generation is the *Codamite.* It resembles a teletypewriter, in that it has a keyboard similar to that of a standard typewriter. But there the similarity ends. A top view of the *Codamite* is shown in Fig. 2-5 and the underside in Fig. 2-6. By conventional manual typing on the *Codamite* keyboard, the operator is able to form the proper characters of the radiotelegraph code which represent the equivalent letters, numerals, punctuation and symbols. Its audible transmissions, therefore, are readily decipherable aurally by anyone familiar with the radiotelegraph code. Exceptionally small and lightweight, the *Codamite* (Ling MG-100) is designed primarily for military, commercial, and emergency applications where portability and battery-powered operations are essential. Its cost at this time puts it beyond the range of the average ham, but those with healthy wallets can well give it more than a passing thought.

For the time being, forget automatic devices for either transmitting or receiving. Such automatic machines are perfectly legal but there will be plenty of time to consider acquiring one, if you are so inclined, after you have passed your license examination.



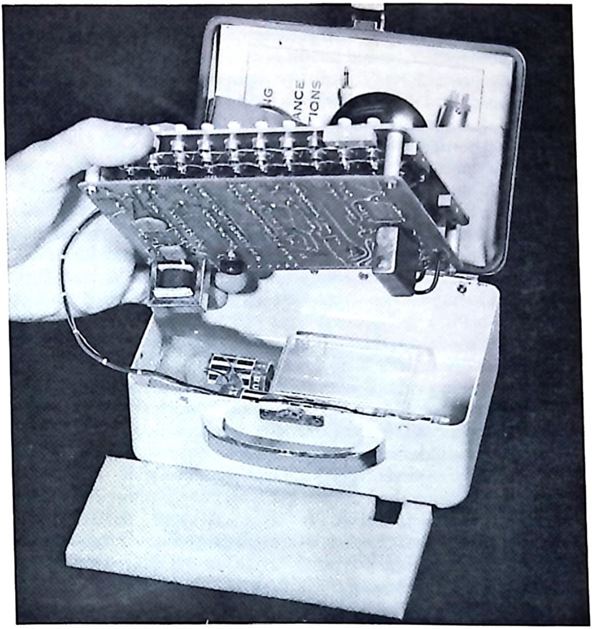
(*Courtesy Ling-Temco Electronics Inc.*)

Fig. 2-5. The **Codamite.**

Suppose we examine in greater detail the means by which you can increase your transmitting speed through more conventional methods.

Manual Keying Devices

In your effort to bring your transmitting speed up to that required for your General or Conditional license examination, you will be wise to concentrate *all* of your practice on use of the old reliable, standard hand key. Stick to "pounding brass" and you will find that you will qualify in both speed and character forma-



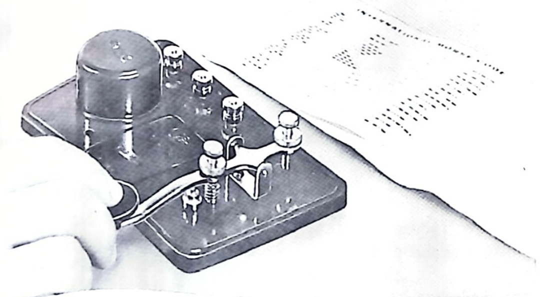
(Courtesy Ling-Temco Electronics Inc.)

Fig. 2-6. Chassis view of the **Codamite.**

tion to an extent which will make your examination code test completely acceptable to the examining officer. Try one of the "trick" keys and you could—and probably will—fall flat on your face! Save them until such time as you have actually become a General or Conditional amateur licensee and have acquired complete confidence in your ability to work the hand key at normal ham speeds. Then, and only then, give thought to the semi-automatic "bug" or the electronic keyer type of "sending machines."

So, to increase your sending speed, practice; to improve your character formation, practice; to eventually acquire a good, fast "fist," practice! To paraphrase a rather common expression, "If you can't lick 'em, practice!" Don't do your practicing on the air; use a key and buzzer or audio oscillator for this purpose. If you are already a licensed Novice, continue your on-the-air normal operation and take any criticism of your sending in good grace and *keep on practicing* with your buzzer/oscillator set-up. If you have purchased or rented an automatic sending machine for your receiving practice, it is probably equipped with terminals for a sending key and perhaps with a built-in code-practice audio oscillator. If so, you can use it to send code to yourself and/or to others within hearing without disrupting the crowded channels of the air lanes. If you don't have such a machine, maybe you have an audio oscillator or a simple buzzer and battery. The buzzer may take occasional fits and "change voice" like an adolescent at times, but it is still very satisfactory. You can purchase a buzzer base-mounted with a hand key and terminals (Fig. 2-7) or by itself for use with your own key for very little, and it will be well worth your small investment during your code training period.

Before we leave this subject, there are two very important points which we wish to make in connection with your sending practice. If you practice with no one other than yourself to listen to your character formation, you could conceivably be doing a pretty poor job! While the printed code characters, whether they be in the older "dot-dash" form or the more recent advance "dit-dah," actually represent perfect character formation, it is physically impossible to show in printed form the idiosyncrasies of the individual, which is known as "style." As your facial features, your bodily form and other distinguishing characteristics make you an individual, your type or "style" or sending code just as definitely identifies you. Believe it or not (you will as you gain



(Courtesy E. F. Johnson Co.)

Fig. 2-7. A typical key-buzzer code practice set.

experience), a competent, experienced telegrapher or radiotelegraph operator can almost always identify the sender to whom he is listening after the transmission of but a few characters, if they have previously worked together a few times! That's right; ask any "old-timer"! Unconsciously you develop a style all your own. Naturally, when you work another amateur station the operator is almost always the station owner as well, so you are pretty safe in assuming that you are talking to "Joe" or "Harry" or "Mable," even though you are using telegraph code which gives you no opportunity to identify the other operator by his voice. Just to show you what we mean by "style," let's take a quick peek at commercial manual radiotelegraph operation. Practically all of the commercial radiotelegraph shore stations who work with ships at sea maintain a "round-the-clock" service. Obviously, no *one* operator can remain on duty continuously; they work in "watches" or "shifts." If you were a commercial radiotelegraph operator sending a message from a ship at sea to a shore station with whom you frequently communicate, how would you know the identity of the receiving operator ashore? And yet many times when I have been the shore station operator and have answered the call of a sea-going vessel, the operator has come back with a casual "GE YB hrs a msg" Mystified? OK, here's a brief breakdown. "GE" means "good evening"; had it been morning it would have been "GM"; afternoon, "GA." "YB"? Practically all commercial, naval and military operators early adopt a "sine"—a couple of letters which may or may not be their initials, but by which they become known practically universally. My "sine" happens to be "YB."

But how did the operator on a ship several hundred miles away recognize the fact that "YB" was at the key ashore? Style of sending! It's all standard radiotelegraph code but just a bit of a drag on a dash here, maybe a slightly different accent on an occasional character or two; it was enough. It spotted the individual at the sending end!

You, too, will develop a style of sending which will become known as your "fist." Let it come naturally; don't try to develop a style. Writers' magazines constantly caution new authors to avoid any attempt to do so; they tell them to let it come and grow naturally and subconsciously. Exactly the same applies to your radio operations. As you gain experience, you will unconsciously develop this peculiarity, and other hams will often recognize your station even though they haven't as yet heard you send your call letters! This is good; it makes you an operator, not a "lid," and that's why you are aiming at the General or Conditional license.

So, if it is at all possible, try to have another operator (preferably one more competent than yourself) listen to your sending practice and make warranted criticisms. He is not going to pay particular attention to any little peculiarities which you may develop; his main concern will be to see that your character formation is easily readable copy to the receiving operator. Your particular style will be something which you can't help, but you'll find it an asset throughout your ham career.

What will it do to you in your examination if such an individual style has developed early in your sending? Unless you are extreme, which is generally the case when an operator attempts to force a style, it isn't going to make one bit of difference. Both the FCC engineer who examines you for a General license and the volunteer examiner for the Technician and Conditional classes are interested only in good, solid, readable sending. They both realize that you are not a machine and therefore not mathematically precise in your character formation; what they want is good code, easily readable.

We are going to make one final point here before we go into the heavier study of the theory portion of the examination. As this point is really important, we have purposely left it until the last so that it would make a deeper impression on your mind. What is it? Just this: you will never increase your code speed receiving ability by copying only that material which you can copy "solid"! By "solid" we mean that you can without difficulty write down every single character you hear without error. If you can do this within the speed brackets of the amateur field, you aren't going to increase your speed one single bit. What you are going to accomplish will be to familiarize yourself more and more with the sound of the characters at the speed at which you hear them and which will, of course, ease the burden of interpreting them *at that speed*. Your mind will wander a bit between characters as they become more familiar through constant use. What you need here is an incentive to make you reach, grasp, grope . . . call it what you will. If you are satisfied to copy solid, without error, at 10 words per minute, you're never going to reach 11 or 12. You're going to have to reach, to grasp, to grope. The General and Conditional examination is plainly tagged at 13 words per minute. So you do a nice job of solid copy at 10; maybe you get 95% of the transmission at 11 or 12 wpm; perhaps only 85% at 13 and down to 65% or so at 15. As far as it goes, that may get you by on a 13 wpm examination; it is possible, of course, that you could manage solid copy for one minute at 13 and make the grade in your code test. You're rubbing the skin pretty thin on the peach, though, if you gamble to that extent. It is more likely that you will miss a letter here and there in every one of the 5 minutes during which you are given a chance to qualify. This means that you go home sadder and wiser and with, we hope, a grim spirit of determination to "show those guys." And that means what? Nothing more than that you will have to get on the ball and build that code speed up to where you can really copy 13 words per minute solid for at least 1 minute out of the 5!

The very best way to assure yourself of that is to keep right on with the practice until sending and copying solid at 13 words per minute is the usual thing with you and at 15 words per minute you get about 95% of what you hear. Go even farther; make about 85% solid copy at 17 or 18 and from 60 to 75% at 20 words per minute. If you'll do that, you'll make your code test easily the first time.

THE OVERALL PICTURE

We have briefly described and illustrated a number of methods which may be used to increase your code speed ability. Some are good, some mediocre; but all will eventually enable you to make the grade in your Federal examination. How soon you can do this depends on two factors; the method you choose, and the amount of time which you can devote to practice. If you have the determination to succeed and are willing to put in a sufficient number of hours, preferably on a regular study schedule, you cannot help but attain your goal. So, what are you waiting for? Choose from the preceding paragraphs the method which you feel is best adapted to your circumstances to increase your code speed—and *get going!*

CHAPTER 3

THE WRITTEN EXAMINATION

Once you've made your code practice arrangements and have set your goal toward increasing your code speed, it's time you begin alternating code practice with study of the technical examination requirements. While this is commonly referred to as the "theoretical" examination, probably it would be more accurately classified as "technical." Actual theory has little place in the questions asked and what little there is, is purely basic. The examination probes your knowledge of the practical applications and adjustments of radio transmitting circuits and equipment. Receivers do not enter into it in any way, and the subject of antennas is touched only where it is necessary to clarify a question having to do with the transmitter output circuits.

Some attention is paid to a few simple operating procedures. Laws, regulations and penalties are considerably emphasized. Schematic circuit diagrams, mostly of a simplified nature, will require you to be familiar with various symbols used to designate components. Many of these you should have already become familiar with through your Novice study, supplemented by your reference to various handbooks and manuals, practically all of which carry rather complete illustrations of such symbolic representations. Continue your familiarization with these designations through your reading and study, paying particular attention to those most commonly used in connection with power supply and transmitter circuits. Coils, capacitors (condensers as they are variously referred to), resistors, vacuum-tube elements, jacks and plugs, key, microphone, quartz crystal and the ground symbol are among those which should receive your greatest attention. Not only will you be asked to draw several simple schematics but printed on your question sheet will probably be a number of such circuits which you will be asked to identify. Your knowledge of symbols, therefore, should be fairly extensive.

As you know, the FCC amateur examination gives you a choice of five possible answers to each question, only one of which is correct. If you mark more than one answer the entire question is counted incorrect. Your answers should be marked with a soft pencil, following the instructions printed on the answer sheet. Be sure to make your marking very plain. Pencil may also be used for any schematic drawings you are asked to make. These do not need to be made with a ruler, but they should be clean, neat and readily decipherable. You will be permitted to erase any errors you make, either on the drawings or your marked answers, but be sure that you erase thoroughly; don't leave any doubt in the examiner's mind what you mean.

For the General, Conditional or Technician license, you will receive about 50 questions, whereas you had only 20 in your Novice test. The answer sheet will contain spaces for answers to 150 questions and the question sheet will specify which 50 you are to use. The passing grade for all classes of licenses is 74%; therefore, if you correctly answer 37 or more of the questions, you'll have it made. Much better if you can do more than just slide by. If you run across a few questions, the answers to which you are doubtful of, don't just take a stab in the dark and mark an answer at random. Sure, there's a rare chance that you might jab the right answer, but don't count on it! Far better for you to take a little more time and try to think it out; you won't be rushed. Two hours is generally more than ample time for a well-prepared applicant to complete his code test and written examination; many do it in less. You will, however, be permitted any reasonable additional amount of time if you require it, so don't rush it.

We've prepared you now for what to expect in the written examination. The following chapters have been grouped by subjects for quick reference, and they simulate the FCC examination in that they are in question and multiple-answer form. While the questions themselves are not the actual questions which you will be asked, they are similar in general scope and make-up, and if you will study them thoroughly you should have no difficulty in attaining a passing grade. We have inserted explanatory material where it has seemed needed to clarify a point. Your aim should be to answer correctly *all* of the questions in this book; not just enough which you believe will let you slip by. Try for at least 85% or 90%, and when you can reach this without hesitancy, you can be fairly confident that you can pass. Many of the answers, you will find, are of the purely "memory" type; laws and regulations, for example. You need not memorize these word for word but study them sufficiently so you are completely familiar with them and can unhesitatingly mark off the correct answer. You will find a number of technical questions in the same category; although these can be treated as "memory" questions, it is better that you know why the answers you have memorized are correct. Study to this end and you will turn out a better ham.

One final point before we pass to the actual question-and-answer sections. If you fail your code test, which will entail a thirty day delay before you can be re-examined, don't drop your study of the sample questions which follow, but alternate them with your code practice. In that way the subject matter which will have to do with the written portion of the examination will remain clear in your mind, and you won't be "stale" when your thirty days are up.

CHAPTER 4

POWER SUPPLIES

It is logical that we start our series of questions, answers and brief discussions with the subject of power supplies. Obviously, without a primary power source, such as the AC house current, to be built up and down to the required voltages, your radio equipment could not function. You will be required, therefore, to have a good understanding of rectification, transformation, and filtering in order to intelligently choose the correct answers to the questions on this subject which will appear in your examination. So, suppose we get right into the meat of the thing. This is not a difficult subject. You should have hardly any trouble if you've been through the Novice study. We will, however, include some review data and questions relating to basic electrical principles and measurements for the benefit of those who have had no previous study on this and the subjects to come.

BASIC ELECTRICITY

Among questions in this category, you will no doubt be asked to define a number of basic units which appear in connection with electrical circuitry. Because you have no way of knowing about which of these you will be asked, your cue is to learn them all. As this is purely a "memory" process, the only help we can give you here is to remind you that most of these unit designations have been named for the scientists who established them; "Volt" for Volta, "Farad" for Faraday, "Watt" for Watt, etc. Doubtless you learned this in high school physics, and you may find it helpful to associate the unit with the name of the man.

Your examination questions may be in various formats. For example, you may be asked "What is the unit of capacity?" or it may be simply, "The unit of capacity is ———." Your task is to choose and mark what you consider the correct answer from the five choices given you.

1. The unit of capacity is:

(A) Volt.
(B) Gilbert.
(C) Coulomb.
(D) Farad.
(E) Watt.

ANSWER: (D)

Put in the second format, the question would read, "What is the unit of capacity?" Obviously, the correct answer is the same: (D).

The electrical units which you may have to identify are:

1.	POWER	WATT.
2.	RESISTANCE	OHM.
3.	CURRENT	AMPERE.
4.	INDUCTANCE	HENRY.
5.	QUANTITY	COULOMB.
6.	CAPACITY	FARAD.
7.	ENERGY	JOULE.
8.	FREQUENCY	CYCLES (per second).
9.	MAGNETO-MOTIVE FORCE	GILBERT.
10.	ELECTRO-MOTIVE FORCE	VOLT.

(This may also be called "potential difference".)

It is advisable that you learn all of the units listed above, since you may be asked to identify any of them.

Firmly fix this list in mind, review it occasionally, and you should experience no difficulty in choosing the correct answers.

All of these units may be measured by suitable instruments or calculated from established formulas. The following questions cover the more common of the electrical units which may be encountered in amateur practice.

1. Power is measured by a:

(A) Voltmeter.
(B) Wattmeter.
(C) Ohmmeter.
(D) Frequency meter.
(E) Ammeter.

ANSWER: (B)

2. Resistance is measured by an:

(A) Ohmmeter.
(B) Ammeter.
(C) Frequency meter.
(D) Voltmeter.
(E) Wattmeter.

ANSWER: (A)

3. A Voltmeter is used to measure:

(A) Current.
(B) Power.
(C) Frequency.
(D) Resistance.
(E) Electrical potential (volts).

ANSWER: (E)

4. Frequency is determined by a:

(A) Voltmeter.
(B) Ohmmeter.
(C) Ammeter.
(D) Wattmeter.
(E) Frequency meter.

ANSWER: (E)

5. An ammeter is used to measure:

(A) Frequency.
(B) Resistance.
(C) Current (amperes).
(D) Power.
(E) Electro-motive force.

ANSWER: (C)

It is obvious that in many cases common sense alone dictates the correct answer. Don't be fooled, however—all of the examination questions won't be so simple!

Let's take a few questions now which will enable you to check your knowledge of one or two other points in basic electricity and permit a more intelligent interpretation of the examination question.

1. What component is represented by this symbol?

(A) Capacitor.
(B) Resistor.
(C) Choke.
(D) Transformer.
(E) Inductance.

ANSWER: (B)

2. What amount of power (in watts) is represented by a current of 12 amperes at a pressure of 150 volts?

(A) 1000.
(B) 500.
(C) 1500.
(D) 1800.
(E) 150.

ANSWER: (D)

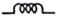
Power is computed by multiplying voltage in volts by current in amperes. If the current flowing in a circuit is given in milliamperes, it must first be converted to amperes.

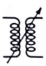
3. Which of the following symbols indicate a variable resistance?

(A)

(B)

(C)

(D) 

(E) 

ANSWER: (C)

4. How is a voltmeter connected in a circuit?

(A) In series.
(B) In parallel.
(C) Series-parallel.
(D) Inductively.
(E) Through a capacity.

ANSWER: (B)

5. An Ammeter?

(A) In series.
(B) In parallel.
(C) Series-parallel.
(D) Inductively
(E) Through a capacity.

ANSWER: (A)

If any of the above fool you, review some of your Novice study to refresh your memory of basic electricity.

VOLTAGE AND CURRENT TRANSFORMATION

In pursuing your study for the Novice examination, you found that a transformer played a pretty important part in the power supply for a ham transmitter; you also discovered why. Your higher-grade exam, for which you are now preparing, may present you with a number of questions on transformers. Suppose we sample some of them to broaden your knowledge of this subject.

1. What part does a fuse play when installed in the primary circuit of a power transformer?

   (A) Acts as a control switch.
   (B) Prevents radio frequency from getting into the power line.
   (C) Prevents overloading the transformer.
   (D) Blocks interference to television receivers.
   (E) Reduces transformer heating.

   ANSWER: (C)

2. If the primary of an unfused transformer were connected to a direct current supply, what would happen?

   (A) Direct current would appear at the secondary.
   (B) The primary winding would burn out.
   (C) The rectifier tube would be damaged.
   (D) The filter capacitor would blow.
   (E) The regulation would decrease.

   ANSWER: (B)

3. In a power transformer, what determines the voltage output of the secondary winding?

   (A) The size of the iron core.
   (B) The size of the wire on the primary winding.
   (C) The ratio between primary and secondary turns.
   (D) The size of wire on the secondary winding.
   (E) The size of the fuse in the primary circuit.

   ANSWER: (C)

4. In a transformer primary supplied with 115 volts AC, what would be the secondary voltage if the ratio of secondary turns to primary were 10 to 1?

   (A) 1150.
   (B) 11,500.
   (C) 11.5.
   (D) 230.
   (E) 115.

   ANSWER: (A)

5. In the same transformer and with the same primary voltage, what would the resulting secondary voltage be if the ratio of secondary to primary turns were 1 to 10?

   (A) 10.
   (B) 115.
   (C) 1150.
   (D) 11.5.
   (E) 230.

   ANSWER: (D)

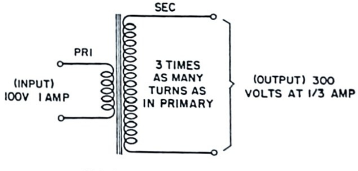
6. Again assuming the above situation but with the ratio 1 to 1, what would be the secondary voltage?

(A) 1.
(B) 11.5.
(C) 115.
(D) 1150.
(E) Zero.

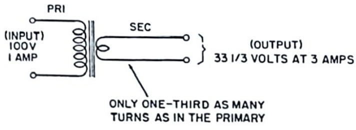
ANSWER: (C)

That should put you pretty straight on "ratio" insofar as tranformer windings are concerned. A secondary winding of, say, 1000 turns and a primary winding of 100 turns would be termed a 10 to 1 secondary to primary ratio; with 230 volts, for example, applied to the primary, 2300 volts would issue from the secondary. A 1 to 1 ratio, then, naturally exists where the number of turns on both primary and secondary are equal and the secondary voltage would be identical with that applied to the primary. Actually, there are a few slight losses incurred in transformation, but as they are trivial in most cases, they can be ignored. The voltage differential between the two windings doesn't suffer sufficiently to be of concern. Design engineers working on the larger, commercial power transformers as used by public utilities calculate such losses and make suitable allowance.

Now let's talk a little about current in relation to transformation, even though you studied this for your Novice ticket. The old saying that you can't get something for nothing is particularly applicable here. If you are going to *increase* voltage through transformer action, you're going to *decrease* current. For ex-



(A) Step-up turns ratio.



(B) Step-down turns ratio.

Fig. 4-1. Transformer action.

ample, put 100 volts at 1 ampere into the primary of a transformer with a 3 to 1 ratio, secondary to primary (Fig. 4-1A), and you'll get 300 volts at one-third of an ampere from the secondary, disregarding the minor losses we mentioned! The opposite action occurs in Fig. 4-1B. If that's clear, see what you can do with a few questions.

7. 115 volts is applied to a transformer with a secondary to primary ratio of 10 to 1; the applied current is 10 amperes; what is the resultant *current* in the secondary winding?

   (A) 10 amps.
   (B) 1 amp.
   (C) 100 amps.
   (D) .1 amp
   (E) 115 amps.

ANSWER: (B)

8. In the situation just described, what would the secondary *voltage* be?

   (A) 115.
   (B) 1150.
   (C) 10.
   (D) 1.
   (E) 11,500.

ANSWER: (B)

In connection with transformers, also remember that by suitable multiple windings one transformer is capable of supplying all of the voltages, at the required currents, that you will need in a ham transmitter. Remember, too, that the *size* of wire used in transformer windings is dependent entirely upon the amount of current such wire will be called on to carry, and the amount of voltage to be handled by the transformer will determine the type and thickness of the insulation used on it. While one transformer will supply all of the power requirements for an amateur transmitter, these are sometimes rather bulky and heavy in the higher-powered amateur equipment. Using powers from maybe 300 watts to a kilowatt, manufacturers as well as ham constructors often use one or more smaller transformers for the low-powered stages and a separate transformer of larger capacity for the final amplifier and modulator supplies. Weigh the advantages when you get your General license, if you intend to use something in the upper power brackets. Your new license status will permit you to use a full "gallon" (KW) of power if you so elect—and can afford it!

RECTIFICATION

The high-voltage output of a power transformer is unsuitable as well as illegal in its "raw" AC state. It has to be changed or "rectified" to pure, direct current with a minimum of AC ripple.

So, our next logical step is to pick up the high-voltage secondary leads from the power transformer and feed them into a rectifier of some type. While recent years have seen much progress in the way of crystal diodes and other means of rectifying alternating current, vacuum or gaseous rectifier tubes remain high in popular use particularly for high power operation. The FCC recognizes this and bases its questions on your knowledge of such rectifiers. You will receive a few questions relating to other, more recent types of rectifying elements however.

A "diode" rectifier of the vacuum-tube type, contrary to the triode, pentode, tetrode and similar tubes, contains but two elements: a filament and a plate. (Fig. 4-2A). In later types an indirectly heated cathode is employed. (Fig. 4-2B). Either the filament or cathode serve the same purpose. A filament is *directly* heated by having its two terminals connected directly to the source of voltage which will make it incandescent and therefore throw off heat. A cathode, on the contrary, is *indirectly* heated, it's filament or heater wires merely serving to heat a surrounding shell (cathode). While we mentioned that a vacuum-tube rectifier of either type (filament or cathode) also contained a "plate," modern practice actually dictates the need for two plates. These plates enter into operation alternately and never work simultaneously.

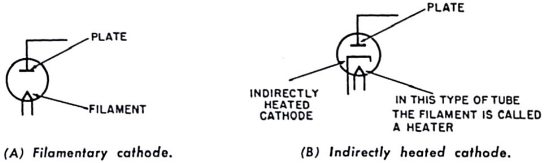


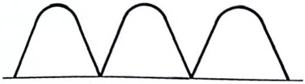
PLATE
FILAMENT
PLATE
INDIRECTLY HEATED CATHODE
IN THIS TYPE OF TUBE THE FILAMENT IS CALLED A HEATER

(A) Filamentary cathode. *(B) Indirectly heated cathode.*

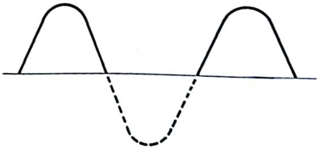
Fig. 4-2. Common vacuum-tube diode symbols.

Those with a single plate are termed "half-wave rectifiers"; with two plates, "full-wave rectifiers." The full-wave or two-plate type is most desirable; the plates working alternately serve to rectify both halves of the high-voltage 60-cycle AC delivered by the high-voltage secondary of the transformer. (Fig. 4-3A). The single plate or half-wave type tube rectifies only one half of the AC cycle. (Fig. 4-3B). This makes filtering—which we will discuss next—more difficult, requiring components of greater values and consequent cost. Two half-wave rectifier tubes can be used, however, and will equal in rectifying properties a full-wave (two-plate) tube. Except in some relatively high power transmitters, however, the single full-wave type tube is employed.

There is another distinction in vacuum-tube rectifiers about which you will doubtless receive several questions. The tubes we have just discussed are of the purely vacuum type, from which all air and gases have been exhausted. A more effective and efficient rectifier tube, known as the "mercury-vapor" type, enjoys fairly wide usage, particularly in the higher-powered transmitters. These, too, are available in both half-wave and full-wave types, containing one or two plates respectively. They differ mechanically in that a small pool of mercury floats internally in the base of the "envelope," as the glass enclosure is known. In operation, the application of voltage to the tube results in producing a vapor from the mercury pool. This vapor is, of course, confined within the tube envelope, providing a more effective conducting path between the filament or cathode and the plate. The mercury-vapor tube has a relatively high current rating which results in a lower internal voltage drop and subsequently a somewhat higher output voltage as compared with a conventional vacuum-tube rectifier. However, a mercury-vapor tube requires more exacting attention than does the vacuum type of rectifier. For example, their filaments or cathode must be permitted to "warm up" for several minutes before application of plate voltage to allow the mercury pool to generate vapor as it warms. They also have a critical inverse peak voltage rating. (This rating specifies the maximum AC voltage that can be applied to the tube without arcing or flashover during the instant the plate is negative and the cathode is positive.) This rating must not be exceeded. Therefore, a choke-input filter must be used rather than capacitor input, because of the high inverse



(A) Full-wave rectifier.



(B) Half-wave rectifier.

Fig. 4-3. Rectifier output voltages.

peak voltages developed with the latter arrangement (filters will be discussed shortly).

In operation, a weird blue-green glow appears inside the mercury-vapor tube envelope as long as plate voltage is applied. In radiotelephone use this is a steady glow with slight variations following the modulation load. Using CW, the glow starts and stops in conformity with the keying. This is a normal characteristic which may be disregarded. The common symbol for a mercury-vapor rectifier tube is shown in Fig. 4-4. The black dot indicates the tube is a gas type.

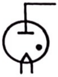


Fig. 4-4. Schematic symbol for a gas-type vacuum-tube rectifier.

Rectifiers of either the vacuum or mercury-vapor type permit the AC voltage received from the high-voltage secondary of the power transformer to flow in only one direction, contrary to the raw alternating current from the transformer which reverses direction in step with the frequency of the supply line. Normally, a 60-cycle (per second) alternating-current supply is the source for amateur transmitting equipment. "Sixty-cycle" means that the AC voltage rises from zero to a "positive" peak, collapses to zero, rises to a "negative" peak and again collapses to zero, repeating this cycle 60 times per second. A half-wave or single-plate rectifier tube rectifies only half of this cycle. Put another way, the AC rises from zero to maximum in the "positive" direction, returns to zero. This upper half passes from the filament or cathode of the rectifier tube to the plate; when the lower half of the cycle rises to negative and returns to zero, the tube is not conducting. The resulting output is a series of unidirectional pulses, occurring 60 times per second. But with a full-wave rectifier, one plate of the tube passes the upper half of the cycle and the second plate then picks up at zero and passes the half that goes negative. Both pulses, however, pass in the same direction. The resulting pulses occur 120 times per second, making the output more of a "ripple" than a pulse! Fig. 4-1 illustrates this more clearly. Since these occur in the same direction on both halves of the cycle, they produce what is commonly referred to as "pulsating direct current." There is sufficient ripple left, even in a full-wave rectifier, to make the resulting voltage illegal as it cannot be classed as "pure" direct current. If it is a radiotelephone transmitter, this ripple will appear as a rather high hum in the modulation circuits and make speech difficult if not impossible to interpret at the receiving station. In addition, the hum produced in the modulation circuits and amplified in the radio frequency circuits will be broad in its frequency characteristics and create interference over a relatively wide band of frequencies, again making it illegal. So our problem now is to get rid of the hum. The next section will show you how.

First, some questions on rectification. Ready?

1. Alternating current from the high-voltage secondary of a power transformer is changed to pulsating DC current by a:

(A) Rectifier.
(B) Motor-generator.
(C) Capacitor.
(D) Resistor.
(E) Choke coil.

ANSWER: (A)

The word "converter," in this instance, is an even more applicable description than the word "rectifier" which we use in connection with vacuum-tube rectifiers. Actually, with a vacuum tube or similar type of device we aren't exactly "rectifying" something, for the dictionary definition of the term "rectify" means to "correct" rather than to "change." We are not "correcting" AC to pulsating DC, but we *are* "changing" it from one to the other. So the term "converter" would be a more appropriate word than the popularly accepted designation of rectifier to apply to the vacuum-tube or other method of changing AC to pulsating DC. You are not going to be too concerned with terminology; however, we thought it wise to expand this explanation in an effort to increase your knowledge of the various designations.

2. What is the most common rectifying device used in amateur transmitters?

(A) Crystal diode.
(B) Rotary converter.
(C) Vibrator.
(D) Vacuum tube.
(E) Transformer.

ANSWER: (D)

3. A half-wave rectifier tube contains:

(A) A filament (or cathode) and two plates.
(B) A filament (or cathode), two grids and one plate.
(C) A filament (or cathode) and one plate.
(D) A filament (or cathode) and one grid.
(E) A filament (or cathode), a screen and a plate.

ANSWER: (C)

4. A rectifier tube with a filament (or cathode) and two plates is:

(A) A full-wave rectifier.
(B) A mercury vapor rectifier.
(C) A half-wave rectifier.
(D) A vibrating rectifier.
(E) A rotating rectifier.

ANSWER: (A)

5. What visual characteristic identifies a mercury-vapor tube under load?
   (A) Cherry red plate (or plates).
   (B) A smoky white haze around filament (or cathode).
   (C) A bluish-green glow.
   (D) Sparking at the base within the envelope.
   (E) Dimming of the filament (or heater/cathode).

ANSWER: (C)

6. The vibrator type of rectifier finds most practical use in:
   (A) Mobile radio applications.
   (B) High-power fixed station use.
   (C) Commercial power line transmission circuits.
   (D) Frequency changers.
   (E) Oscillation generators.

ANSWER: (A)

7. The ripple frequency at the output of a full-wave rectifier operating from a conventional 60-cycle AC source is:
   (A) 60 cycles.
   (B) 30 cycles.
   (C) 120 cycles.
   (D) 15 cycles.
   (E) 220 cycles.

ANSWER: (C)

8. The current issuing from a radio power supply rectifier is:
   (A) Alternating current (high voltage).
   (B) Pulsating direct current.
   (C) Pure direct current.
   (D) Low-voltage alternating current.
   (E) Radio-frequency current.

ANSWER: (B)

9. How does the voltage output of a mercury-vapor rectifier tube compare with that of a conventional vacuum-tube rectifier? Is it:
   (A) Less than?
   (B) The same?
   (C) Half as much?
   (D) Greater?
   (E) Twice as much?

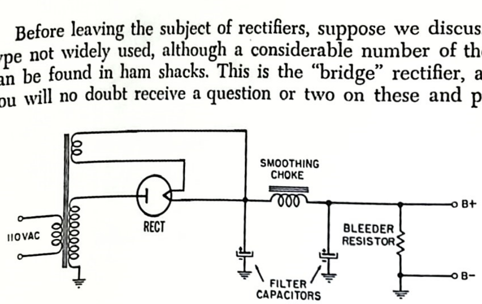
ANSWER: (D)

Remember we mentioned previously that a mercury-vapor tube has a lower internal voltage drop by reason of the higher conducting path provided between cathode and anode (plate) by reason of the mercury vapor. Obviously, then, the voltage output from a mercury-vapor tube would be greater than in an equivalent high-vacuum tube, the latter having a greater internal voltage drop. However, the mercury tube is more critical in its peak current and inverse peak voltage ratings. For this reason, the manufacturer's specified maximum voltages must not be exceeded with mercury-vapor tubes.

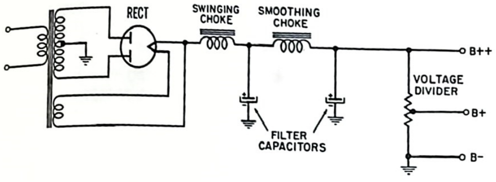
10. Mercury vapor tubes should never be used with:
   (A) A choke-input filter.
   (B) Any filter.
   (C) A capacitor-input filter.
   (D) Manufacturer's voltage ratings.
   (E) Amateur radio power supplies.

ANSWER: (C)

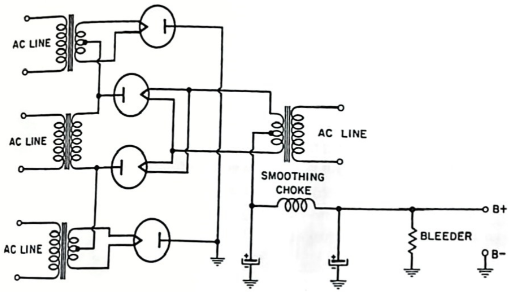
Before leaving the subject of rectifiers, suppose we discuss a type not widely used, although a considerable number of them can be found in ham shacks. This is the "bridge" rectifier, and you will no doubt receive a question or two on these and possibly be asked to make a schematic drawing of one or identify one from a schematic. First, a bridge-type rectifier may use either high-vacuum or mercury-vapor tubes and will require additional filament transformers as well as twice as many tubes.



(A) Half-wave.



(B) Full-wave (center-tapped secondary).



(C) Full-wave bridge.

Fig. 4-5. Three basic power supply circuits.

Some economy is experienced with this arrangement in that the output voltage is *double* that of a half- or full-wave rectifier, although the output current is *halved*. For low-and medium-power transmitters a lower voltage power transformer can be used, if it is adequate in both voltage and current capacity to provide the desired wattage at its output. Wattage, you'll remember, is a measure of power and is arrived at by multiplying the output current by the output voltage. In other words, if you supply a bridge rectifier with 400 volts at a current of 200 milliamperes (.2 of an ampere) the resulting output from the rectifier will be 800 volts at *100* mils, give or take a small percentage. If this is adequate for what you want, then the lower-voltage transformer will satisfy the requirements, although the economy is questionable when cost of additional tubes and filament transformers is considered. Fig. 4-5 shows the three fundamental types of power supply circuits discussed in this chapter. You should become familiar with each circuit; you may be asked to sketch one or more from memory.

The crystal diode or, more properly termed, *semiconductor,* in contrast to the tube type of rectifier, has no filament or heater. The elements are generally silicon or germanium as basic material. If these minerals are very pure, they constitute poor conductors. When injected with certain impurities, their conductivity increases. Adding a chemical such as phosphorus to the basic material creates a negative charge carrier defined as the "N" element. A positive charge carrier or "P" element is produced by impregnating the basic material with boron or a similar chemical. A sandwich is made of two basic elements of the P and N type and connecting leads brought out through a protective enclosure. Connected to observe proper polarity, these semi-conductors permit current to flow in one direction only as in the vacuum or mercury type of tube diodes.

Currently, an individual crystal diode will handle less power than the larger rectifier tubes but crystal diodes may be connected in series to provide greater voltage handling capacity. Choice of such a series of crystal diodes as against a single tube rectifier, is often based on the economic factor. Silicon crystals are generally preferable to germanium due to higher temperature tolerance and the ability to handle greater power. Zener diodes, a type introduced fairly recently, incorporate certain characteristics which make them even more suitable for power applications and are finding increasing favor with electronic designers.

11. A bridge rectifier requires:
    - (A) Twice the initial RMS transformer voltage.
    - (B) Only one filament transformer.

(C) Twice the number of tubes used in half- or full-wave rectifiers.
(D) No warm-up period if mercury-vapor tubes are used.
(E) A larger choke coil in the filter system.

ANSWER: (C)

12. How does the output *voltage* of a bridge rectifier compare with that of a full-wave, center-tapped arrangement? Is the output voltage of the bridge:

(A) Less?
(B) Twice as much?
(C) Same?
(D) Triple?
(E) Half as much?

ANSWER: (B)

13. How does the output *current* of the bridge rectifier compare with that of the full-wave, center-tapped arrangement? Is it:

(A) Half as much?
(B) The same?
(C) Twice as much?
(D) Slightly more?
(E) Three times as much?

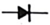
ANSWER: (A)

14. Which of the following are preferred for crystal diodes:

(A) Silicon?
(B) Germanium?
(C) Selenium?
(D) Carborundum?
(E) Quartz?

ANSWER: (A)

15. Show the schematic symbol designation for a semiconductor diode of the crystal type:

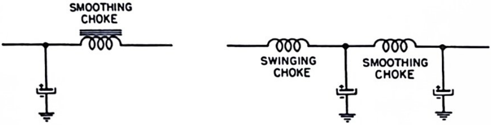
ANSWER 

At this point you should have gained a considerably better overall understanding of rectification and should be able to answer the questions you will be asked concerning the subject on your written examination. Now it's time that we pass on to the next unit of the power supply, the filter system.

FILTER SYSTEMS

As you learned earlier, the pulsating direct current produced by a rectifier is illegal by reason of the ripple component which tends to modulate the radio frequency (RF) carrier. It is essential not only from the legal requirement standpoint but to insure intelligible speech transmission that the ripple be eliminated to as great an extent as possible. This is the function of a filter system which, properly designed, will result in practically pure direct current, with no noticeable pulses on the output side of the filter. We use the term filter *system* inasmuch as a correctly designed filter must contain at least two elements, one or more capacitors and one or more iron-core choke coils. It is entirely possible to reduce the ripple to some extent through use of only one capacitor and no choke, or by using a choke alone. The result, however, still does not produce the required pure direct current. A combination of capacitance and choke components working together, however, fulfills the requirement for pure DC to an extent which the state of the art permits. A filter capacitor should, of course, have a voltage rating equal to the output voltage of the rectifier *plus* a 50% safety factor. For example, a capacitor to be used with a 400-volt rectifier output should be rated to withstand 600 volts. The value of such capacitors is somewhat variable in both factory-built and kit-form transmitters, as well as in those built from various design data to be found in periodicals and handbooks, from 2 microfarads up to as much as 30 microfarads. A good average value for all practical purposes is generally from 4 to 8 microfarads. The purpose of a filter capacitor, whether it appears ahead of a choke as in a capacitor-input filter or following the choke where a choke-input system is used, is to bleed off or by-pass the AC component (ripple) remaining in the rectifier output. At the same time, the capacitor effectively blocks the flow of DC, permitting the latter to pass to the transmitter circuits without hindrance.

A single-section filter will consist of one capacitor and one choke (Fig. 4-6A); such a filter system may be either choke input or capacitor input. In most cases, this simple filter arrangement will effectively reduce the AC component to a negligible value which will be legal and permit good quality voice transmission. A two-section filter, using *two* chokes and *two* capacitors (Fig. 4-6B), will be even more effective and may, in some instances, be required to achieve the desired results. Choke input is gen-



(A) Capacitor input. *(B) Choke input.*

Fig. 4-6. Basic filter circuits.

erally preferable in a filter system, as it permits better voltage regulation and reduces possible damage to the rectifier tube occasioned by "kick-back" voltages from the capacitor if capacitor input is used. The filter choke, in addition to assisting in voltage regulation by its automatic change of inductance under varying load conditions, readily passes DC and also serves to smooth out any small amount of AC ripple which may still remain in a capacitor-input filter or in reducing the AC component which will be finally wiped out by the following capacitor in the choke-input filter system. There are two types of chokes used in power supplies of this type. One is commonly known as a "swinging" choke; the other, a "smoothing" choke. The swinging choke has a somewhat more pronounced change in its inductance under varying load conditions. For example, under a condition of decreasing load current the swinging choke provides increased inductance which tends to keep the output voltage constant. Moreover, this choke provides slightly better regulation than a smoothing choke and is somewhat less costly. Either the swinging or smoothing type may be used in a single-section filter system. In a two-section filter arrangement, the ideal is to use choke input, the input choke being of the swinging type, wired in series with a smoothing choke (Fig. 4-6B). The first filter capacitor should be connected from the junction between the two chokes to ground (chassis) and the second capacitor following the smoothing choke. Like capacitors, any choke should have a voltage rating adequate for the voltage it will be expected to carry and should provide a safety factor of at least 25%. Needless to say, it must also be capable of handling the expected current plus a good safety factor. An example would be a choke to be used with a 400-volt supply from the rectifier; its insulation and voltage rating should be based on at least 500 volts. A normal current of 125 milliamperes is expected to flow through its windings; one rated at 200 milliamperes would be a safe value to choose.

One other component can well be considered as part of the filter system, although from the standpoint of actual "filtering" it plays no part. This is the "bleeder resistor" which, if provided with take-off taps or a slider for various voltages, is more commonly referred to as a "voltage divider." (See Fig. 4-5B). We will consider it a part of the filter system, however, in that it does assist somewhat in voltage regulation by providing a constant though relatively small load across the rectifier filter system. As either a straight bleeder or as a voltage divider, it also performs an additional and very important purpose. Being constantly connected across the output of the filter system, it serves to bleed off to ground any residual voltage remaining in the filter capacitors after the power is turned off. A certain amount of such voltage remains in the capacitors even with no voltage applied and can cause a nasty shock to the ham who has turned off the power and had occasion to do some internal work on his transmitter. A capacitor may hold a charge for only a few seconds, several minutes, and often a half hour or more. Cases have been reported where an impressive amount of voltage has remained in some of the higher quality capacitors for days! With a bleeder or voltage divider, this voltage drains off to ground within a matter of seconds and the equipment can be safely worked on. There is, however, always a chance that a bleeder resistor or voltage divider has failed; its resistance winding has become open. To play it safe whenever you must work internally on your transmitter, always first ground the positive end (high side) of the bleeder momentarily to the chassis, using a well-insulated screwdriver or a short piece of heavily insulated wire! Better be safe than sorry, you know!

Now, let's see how much information you've absorbed from our discussion of filters. Several questions here should determine that.

1. A filter system serves to:

   (A) Change AC to DC.
   (B) Remove the AC component from the rectifier output.
   (C) Removes the DC.
   (D) Removes both AC and DC.
   (E) Increases the rectifier output.

ANSWER: (B)

2. What would be the effect of a shorted filter capacitor in a power supply using a power transformer with an unfused primary?

   (A) Reduce the DC output voltage.
   (B) Double the ripple frequency.
   (C) Damage the rectifier tube.
   (D) Burn out the choke coil(s).
   (E) Increase the DC output current.

ANSWER: (C)

Don't let this one toss you; reference to your text and to Fig. 4-5 will indicate that the filter capacitors are connected directly across the positive and negative high-voltage supply from the rectifier tube. A short-circuited capacitor would be the same as deliberately placing a wire across the supply from the rectifier. This would place a tremendous load on the tube, and unless a fuse were in the transformer primary circuit or the defect was noted immediately and the line cord pulled, the tube would suffer damage, perhaps becoming completely useless. Possibly even the transformer secondary itself would burn out. A short-circuited filter capacitor will usually manifest itself by causing the plates of the rectifier tube to turn cherry red. In a mercury-vapor tube a considerable increase in the brilliance of the blue-green glow would be evident.

3. Which type of filter system is considered most effective?

    (A) Capacitor only.
    (B) Capacitor input followed by a single choke.
    (C) Choke input followed by single capacitor.
    (D) Choke input using two chokes and two capacitors.
    (E) Capacitor input using two chokes and two capacitors.

ANSWER: (D)

4. What is the primary function of a bleeder resistor?

    (A) To reduce the DC voltage.
    (B) To protect the filter capacitor.
    (C) To safely bleed off dangerous residual voltages.
    (D) To protect the filter chokes.
    (E) To protect the rectifier tube.

ANSWER: (C)

There are a number of minor gadgets and refinements which may be found in some amateur power supplies, such as the "hash" filters sometimes used with mercury-vapor tubes, equalizing resistors used in connecting filter capacitors of unlike capacity in series to provide a higher voltage breakdown, and a number of by-pass capacitors scattered here and there throughout the power supply circuits. All these are considered irrelevant to the subject of this manual. Information on the accessories mentioned is readily available in the various handbooks and should become a part of your study from time to time to increase your familiarization with the various phases of ham radio. Such knowledge, like everything we learn, is valuable, but need be of little concern to you for your General examination.

CHAPTER 5

RF OSCILLATORS, INTERMEDIATE AMPLIFIERS, AND MULTIPLIERS

In the previous chapter we discussed the methods used to step the relatively low 60-cycle AC house current up or down, and to convert this current into the high-voltage DC required by radio equipment. Now, we will see how the direct current manufactured by the power supply can be utilized to produce AC—only at a much higher frequency than the original 60-cycle source voltage. After conversion the AC voltage will vary at an RF (radio frequency) rate. The RF frequencies in the amateur field extends from a low of 1,800,000 cycles, more commonly referred to as 1800 *kilo*cycles, up into the millions of cycles (called megacycles for the sake of convenience). The frequencies currently in use run as high as four and five hundred megacycles, and as technology advances, more and more amateurs as well as commercial interests are pushing the upper limit farther and farther into the microwave field. The field for experimentation is wide open, and here the Technician-class licensee who is seriously interested in contributing to development can do his most productive work. You need not be concerned with the intricacies of micro-wave work in connection with the examination for General, Conditional or Technician licenses. We will confine our discussions to the equipment used on frequencies which are in more common use in the amateur bands and on which you will be questioned. To obtain a better understanding of RF energy, let's begin with a discussion of the "heart" of any radio transmitter—the oscillator.

The Quartz Crystal Oscillator

The piezoelectric crystal, the most popular of which is quartz, is, of course, rather familiar to those who passed the Novice examination. Such a crystal, when properly connected and with the application of suitable RF voltage, will vibrate mechanically at a specific frequency which is determined by the thickness of the crystal, the way it is cut, and, to a minor degree, several other factors. The physical vibrations of the crystal in turn generate a high-frequency voltage output from the crystal itself. This voltage is used to control the operating frequency of the oscillator. A good crystal (or "rock" as hams more commonly refer to them) will oscillate strongly at the frequency for which it has been cut and mechanically ground. At the same time, however, harmonic frequencies are also generated. These occur at multiples of the fundamental frequency and are somewhat weaker although still readily apparent. The *fundamental* frequency of the crystal is known as the "1st harmonic"; *twice* the frequency as the 2nd, three times, the 3rd, etc. The fundamental or any harmonic (within limits) can be used; all others must be suppressed. Until recently, the practical limit, at least from the amateur standpoint, was the 5th or 6th harmonic with most hams using no more than the 3rd or 4th. Radiation of harmonics other than the one producing the desired signal is not only undesirable but illegal as well. Steps must be taken to eliminate or at least minimize such harmonics so that they cannot cause interference in other parts of the ham bands or to other radio services. Harmonic elimination will be discussed a little farther along in connection with intermediate frequency amplifiers and frequency multipliers.

Although crystals are precisely ground to vibrate at a predetermined frequency, there are certain temperature-frequency characteristics that must be taken into consideration. Shortly after a transmitter is turned on, the crystal is exposed to heat radiated from tubes and similar components. Because of this heat, the fundamental frequency has a tendency to "drift" gradually. How far depends on many factors; it is never very much, but a drift of a few kilocycles *could* take an amateur operating very close to the edge of a band outside of the legal band limits and subject him to a citation for operating "out of bounds"! Roughly, it may be said that the higher the quality of the crystal and the more constant the heat it is subjected to after a warm-up period, the less the drift. Often commercial equipment has its crystal enclosed in an "oven" which is nothing more than a small enclosure containing not only the crystal but a small heating element as well. This element receives power from the filament circuit. The more elaborate ovens also contain a small thermostat; this combination maintains a more nearly constant temperature on the crystal, thereby minimizing the drift. Relatively few amateurs use ovens; certainly fewer use those which are thermostatically controlled. The drift, for an analogy, can be compared to that in your receiver; as it warms up, you readjust the tuning dial slightly to follow the drift; eventually it settles down and the tuning remains much more stable than it was initially.

The frequency-temperature characteristics of a crystal should be given careful consideration when ordering a crystal ground for operation near the end of a band. The following formulas can be used to calculate the nearest *safe* frequency for which the crystal should be ground and still provide legal operation.

When ordering a crystal for operation as near as possible to the *low* end of a band, the required crystal frequency can be obtained from the following formula:

$$f_x = \frac{f_L}{1-n}$$

where,

f_x – is the crystal frequency,

f_L – is the lower band limit,

n – is the manufacturer's frequency tolerance (specified on crystal holder as a decimal).

For operation at the *high* end of the band, the formula is expressed as:

$$f_x = \frac{f_u}{1+n}$$

where,

f_x – is the crystal frequency,

f_u – is the upper band limit,

n – is the manufacturer's specified frequency tolerance.

Add at least 1 kc to the answer obtained from the *low* end of the band formula to allow for frequency drift caused by heat. *Subtract* at least 1 kc from the answer obtained using the high-end formula for the same reason.

You should memorize these formulas and work several problems based on them, because you are almost certain to receive one or two questions on this subject in your examination. You will find a couple of sample questions and answers based on these at the end of this chapter; use them as a guide and work several of your own makeup so you will become familiar with the process.

Crystal oscillators are seldom used as transmitters feeding directly into a radiating system, although they will, of course, operate in this manner. The power output of a crystal oscillator is ordinarily very low—a matter of only 5 watts or so—although some higher-powered oscillators are capable of delivering 35 to 50 watts under the right conditions. This is, however, not good practice; the crystal is being worked to the danger point and harmonic radiation on spurious frequencies is much more liable to occur. It's far better to amplify the output of a low-powered crystal oscillator, using one or more stages of amplification before the output reaches the antenna. When so used, the oscillator is often referred to as the "driver" stage, as it serves to excite or drive the following stage. More about that in the next section.

Many hams have the impression that being crystal controlled means complete assurance of operation on the correct frequency. While to a certain extent this is true, allowing for a slight drift, it cannot be accepted as an absolute *guarantee* that you are working on the frequency with which your crystal is marked. We previously mentioned that, in addition to their fundamental frequency, crystals also generate certain harmonic frequencies which must be eliminated or greatly attenuated. Such attenuation is accomplished by proper tuning of the oscillator, and the intermediate and final amplifiers. The required adjustments can be made without too much difficulty by a capable operator. In the hands of an inexperienced operator, however, great care must be exercised when tuning the oscillator so that it is not inadvertently adjusted to a *harmonic,* rather than the fundamental frequency. For example, suppose you were using a 3980 kc crystal. You call CQ but receive no replies. If you had unintentionally tuned the oscillator circuit to the *2nd* harmonic of the crystal, you would be radiating at *twice* the fundamental frequency (7960 kc)! Not only would you get no replies while listening around 3980 kc for such, but 7960 kc puts you way, way out of the amateur bands. This, of course, leaves you wide open for a citation from an FCC monitoring station!

Naturally, the FCC frowns pretty heavily on things like this and, therefore, requires that an amateur station be equipped with means *other* than simply a crystal, to measure the transmitting frequency as well as to determine harmonic radiation, if any. Ordinarily, a good, stable ham receiver is acceptable if it has an accurately calibrated dial and a low degree of drift.

For greater accuracy a wave meter (also designated "frequency meter") can be used for precision measurements. A frequency meter, like any other man-made device, is not perfect. Small errors in reading are possible due to parallax, drift, etc.

Some meters have only slight inherent errors while others have comparatively more. The meter manufacturer generally specifies the possible error in a decimal percentage. Frequency determination in such cases, where the percentage of error is known, can be calculated in a manner very similar to that used to calculate the safest crystal frequency for band-edge operation. To determine how close to the edge of a band you can set your transmitter, using a frequency meter with a known percentage of error, use the following formulas:

1. For the low end of the band

$$f_x = \frac{f_L}{1-n}$$

where,

f_x — is the frequency indicated on wave meter,
f_L — is the lower band limit frequency,
n — is the decimal percentage of error.

2. For high end of band

$$f_x = \frac{f_u}{1+n}$$

where,

f_x — is the frequency indicated on the wave meter,
f_u — is the upper band limit frequency,
n — is the decimal percentage of error.

It is best to memorize these formulas also; you will very likely be given a question based on their use to answer. Note that it is not necessary to add or subtract from the result an arbitrary number of cycles representing possible drift as you did in connection with the band edge formulas. Work a few problems for yourself in this connection using any arbitrary decimal percentage, preferably between 0.50 and 0.85%, which is average.

So much for the crystal oscillator; the questions which follow should enable you to test your knowledge of the preceding discussion:

1. What is the primary purpose of a crystal-controlled oscillator?

(A) To prevent direct current from reaching the antenna.
(B) To prevent commercial AC frequencies from modulating.
(C) To permit radiation at any desired frequency.
(D) To restrict RF oscillation to a definitely defined frequency.
(E) To provide flexibility in frequency selection.

ANSWER: (D)

2. A multiple of the frequency for which a crystal is ground is known as:
   - (A) The fundamental frequency.
   - (B) A harmonic of the fundamental frequency.
   - (C) A frequency multiplier.
   - (D) A frequency amplifier.
   - (E) A frequency suppressor.

ANSWER: (B)

3. A crystal ground for a specific frequency can be used:
   - (A) Only on the frequency for which it is ground.
   - (B) On any other selected frequency.
   - (C) On any multiple of its fundamental frequency.
   - (D) On half of its fundamental frequency.
   - (E) On any lower frequency.

ANSWER: (C)

4. Using a crystal oscillator only as a transmitter could result in:
   - (A) Spurious radiation (unwanted harmonics).
   - (B) Greater RF output.
   - (C) More stable output.
   - (D) Elimination of interference to other stations.
   - (E) No radiation.

ANSWER: (A)

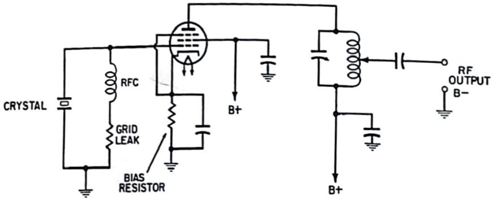


Fig. 5-1. Basic crystal-controlled pentode oscillator circuit.

5. Draw a diagram of a crystal-controlled oscillator, using a pentode tube (Fig. 5-1). Show proper supply voltage polarities; be able to identify the circuit.

6. Draw a diagram of a simple Pierce crystal oscillator (Fig. 5-2) using a triode tube.

7. Desiring to operate as closely as possible to the lower limit of the 28-29.7 mc band, using a crystal with a calibration tolerance of 0.05% of its specified frequency, for what frequency should you order a crystal? Allow 1 kc for temperature and circuit constant variations. Use nearest whole number.
   - (A) 28,350.
   - (B) 28,200.
   - (C) 28,015.
   - (D) 28,010.
   - (E) 28,300.

ANSWER: (C)

8. For what frequency would you order a crystal for operation at the nearest legal band edge at the upper end of the 3500-4000 kilocycle band, using the nearest whole number to specify the frequency you would order. Allow 2 kc for circuit constant and temperature variations. Manufacturers tolerance is specified as 0.04.

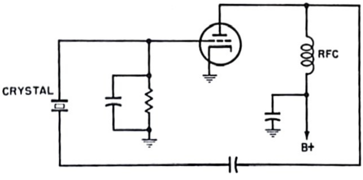


Fig. 5-2. Crystal-controlled Pierce oscillator circuit using a triode tube.

(A) 3998 kc.
(B) 3996 kc.
(C) 3997 kc.
(D) 3999 kc.
(E) 3995 kc.

ANSWER: (B)

9. Used with a crystal oscillator, a frequency meter (or wave meter) is used to check:

(A) The presence of standing waves.
(B) The intensity of oscillation.
(C) The wave shape of the output.
(D) The heating of the crystal.
(E) The exact frequency of oscillation.

ANSWER: (E)

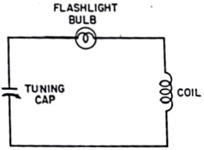


Fig. 5-3. A simple wavemeter using a flashlight bulb as an indicator.

10. Draw a diagram of a simple wave meter using a flashlight-bulb indicator (Fig. 5-3).

The foregoing text and questions should acquaint you pretty well with crystal oscillators in general. In addition, read anything else on which you can lay your hands, pertaining to the subject, to increase your knowledge. The better understanding you have of crystal theory and functioning, the more readily you can answer questions. For our next subject, we will discuss the very popular variable-frequency oscillator (VFO) which you will be privileged to use as a Technician, Conditional, or General class amateur.

The Variable-Frequency Oscillator

The variable-frequency oscillator, or VFO as we shall refer to it from here on, is actually a very stable oscillator whose operating frequency can be continuously varied over a rather wide range. Like the crystal-controlled oscillator, its function is to generate radio-frequency oscillations. It's only chief difference from the crystal-controlled oscillator is that any frequency within its range may be selected by the operator.

It might be interesting to note at this point that, contrary to popular belief by many hams, VFO's are as old as radio itself. Maxwell, in the 1860's produced a spark discharge which created a radio-frequency wave in space although he did not realize it. His spark "oscillator," while of fixed frequency, *could* have been varied in frequency, had he but known it. Hertz, using the spark coil of Maxwell in the later '80's, found that, by varying the length of the rods supporting the balls of the spark gap, he could produce greater or lesser intensity of spark in his "responder" which was nothing but a loop of wire with a minute gap in it, placed in the radiation field—a few feet from the spark gap in his case. He tried different-sized loops and varied his spark-gap rod lengths to electrically match, thereby varying the frequency of his oscillator . . . in effect he had a "VFO"! A short time later Marconi discovered that, by using helical coils of bare wire in his transmitting equipment and clipping his spark-gap leads to include more or less turns in the circuit, he could achieve different output frequencies or "wave-lengths" as they were then termed. Again, a "VFO"! As the art advanced, commercial companies as well as amateurs took advantage of this adjustable frequency feature which permitted regulation of the frequency or wave-length of their transmissions over as wide a range as the capacity of their coils permitted.

It was not until the advent of vacuum tubes as RF generators that the VFO of today began to take shape. Where with the early spark transmitters it had been necessary to move a clip on a wire-wound helix several turns to affect an appreciable change in wavelength, the inherent sharpness of the emitted waves from a vacuum-tube transmitter made it possible to obtain a considerable shift in the output frequency by moving the clips only a turn or so and often a mere fraction of a turn. It was not long before it was realized that, with the demonstrated efficiency of the vacuum tube, only a fraction of the power required for a given distance coverage with spark transmission, was necessary. This permitted the use of smaller coils, and it was not long before both amateur and commercial designers were tapping these coils at several points by means of adjustable clip leads connected to a switch. Any one of a number of wavelengths could then be selected by merely switching to the proper tap. This was more of an "adjustable" than a "variable-frequency oscillator," as it was not *continuously* variable. Next came "variometers" which permitted *continuously* variable adjustment of frequency through the range of the equipment. Variometers, however, were costly, awkward to make, and somewhat limited in their power-handling capabilities. Therefore, they found little favor with hams. Soon it was realized that the operating frequency could be changed by varying *either* the inductance *or* capacity of the tuned circuit. Designers got busy and soon manufacturers were offering the ham variable capacitors of relatively low value (it didn't take much for 200 meters . . . you could always use a larger coil!). These had wide-spaced plates (except on very low power) to prevent the flashing-over which was experienced in early attempts to use a receiving type of capacitor. The VFO was born! Soon it was difficult to find a ham station which did *not* incorporate this early form of VFO. Remember, in those early days the "VFO" was also the final amplifier stage; the output of the VFO fed directly to the antenna *without* any intermediate stages and often was capable of power inputs up to and beyond 500 watts! There was no crystal to heat and crack; power within the legal limit was taken directly from the oscillator! Hams were a bit slow in realizing that they no longer *needed* that half or full kilowatt, as they did in spark transmission, to effect many times the distance using vacuum tubes. The size of components was reduced. Intermediate and final amplifiers soon came into being and permitted even further reduction in component size and power requirements in the oscillator. The result, today, is a compact VFO with a power input ranging from only 2 to 5 watts and with greatly improved stability. Modern practice is to feed the VFO output into additional stages where it is amplified before reaching the antenna. Let's look at a present-day VFO. Basically it is just what the hams were using in earlier vacuum-tube days; an *adjustable* coil and a *continuously variable* capacitor. However, no longer are clip leads used on the coil to shift to various bands (although initially, "bands" as we know them today, did not exist); small rotary tap switches which we know as "band switches" shortly replaced them. Taps are now permanently soldered to the small oscillator coil at predetermined points, and the proper amount of inductance is selected when the band switch is rotated to the desired band. The actual frequency *within* the band is chosen by rotation of the variable capacitor to the desired frequency as indicated on a calibrated scale.

Modern VFO's of the better type closely approach and often equal the stability of a crystal oscillator. Good design dictates rugged, though not necessarily large nor heavy, construction. Complete shielding and adequate ventilation should also be provided within the VFO. Voltage regulation should be excellent; many have voltage regulating tubes to insure this. Some even go so far as to be "self-powered" (have an independent power supply) to insure even more against voltage variation. All of these things contribute to stability of output.

VFO's resemble the crystal oscillator in other ways as well. They may be used directly into an antenna as a low-powered transmitter but, like the crystal oscillator, will suffer some stability loss. There is also the danger of their harmonics reaching the antenna and being radiated into space. Again like the crystal, their power output is so low that their transmission capability is limited to a relatively few miles. All of these points indicate that neither the VFO nor the crystal oscillator should be operated by itself as a transmitter; both should feed an additional stage which may either be an intermediate amplifier or directly into a final amplifier. The intermediate or "buffer" stage which drives the final amplifier is preferable, and is generally used in the moderately powered and moderately priced transmitters of the better class. Many low-power, low-priced transmitters eliminate the intermediate stage satisfactorily and they perform well and legally, but in the more powerful rigs, the extra intermediate stage is that much more assurance that spurious harmonics will not get through to the final amplifier and the antenna.

Any one of several different oscillator circuits have been used by manufacturers of amateur VFO's as well as by the ham constructor. Some favor the Hartley, others the Colpitts; The Clapp oscillator also enjoys considerable popularity. There are a number of variations of all of these, but these are the basic circuitry for most VFO's currently in use. Basic Hartley and Colpitts circuits, which are found in the majority of VFO's, appear in Figs. 5-4 and 5-5 respectively. You should learn them, as you may encounter them in your examination questions. Likewise, two other basic circuits which will operate as a VFO are shown—the electron-coupled oscillator and the tuned-plate/tuned-grid. Although these are not in as common use as the Hartley and Colpitts, learning them will do you no harm and it is very possible that you will be asked to draw one or to identify an FCC-drawn basic schematic by name. Shall we go into a little questionnaire now to test your knowledge regarding the VFO?

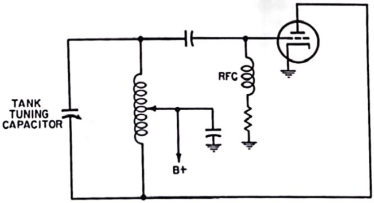


Fig. 5-4. Basic Hartley oscillator.

1. Draw a diagram of a basic Hartley oscillator circuit. (Fig. 5-4).
2. Draw a diagram of a basic Colpitts circuit (Fig. 5-5).

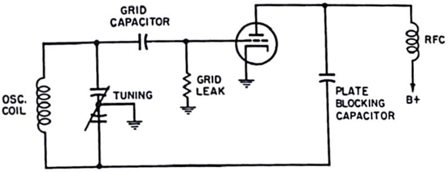


Fig. 5-5. Basic Colpitts oscillator.

3. What does the tuning knob on a modern VFO control?
   - (A) The amount of inductance in the circuit.
   - (B) The amount of capacitance in the circuit.
   - (C) Both the capacitance and inductance of the circuit.
   - (D) Taps on the inductance coil.
   - (E) Output coupling to the next stage (or antenna).

ANSWER: (B)

4. Draw a basic schematic of an electron-coupled oscillator (Fig. 5-6).
5. Draw a basic diagram of a tuned-grid/tuned-plate oscillator (Fig. 5-7).
6. How is the proper amount of inductance for the various bands selected in the VFO circuit?
   - (A) By the tuning knob.
   - (B) By clipping to various turns of the coil.
   - (C) By a tapped switch (band switch).
   - (D) By a sliding contact.
   - (E) It is not changed.

ANSWER: (C)

7. What are the two most popular oscillator circuits used in VFO's?
   - (A) Tri-tet and Clapp.
   - (B) Hartley and tuned-plate/tuned-grid.
   - (C) Colpitts and Pierce.
   - (D) Hartley and Colpitts.
   - (E) Electron-coupled and Clapp.

ANSWER: (D)

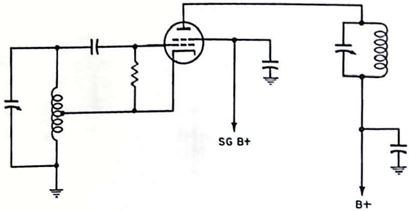


Fig. 5-6. An electron-coupled oscillator.

8. Where is a quartz crystal used in a VFO?
   - (A) In the grid circuit of the oscillator tube.
   - (B) They are not used.
   - (C) In the output circuit.
   - (D) In the cathode circuit.
   - (E) In series with the plate circuit.

ANSWER: (B)

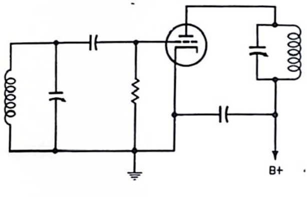


Fig. 5-7. Basic tuned-grid/tuned-plate oscillator.

9. In a VFO supplied with regulated voltage, the voltage regulation is generally accomplished by:
   - (A) A variable resistance.
   - (B) A fixed resistance.
   - (C) A voltage-regulator tube.
   - (D) A filter condenser across the high-voltage supply.
   - (E) A filter choke in series with the high-voltage supply.

ANSWER: (C)

The foregoing paragraphs have pretty well taken care of about anything you will experience in connection with crystal oscillators and variable-frequency oscillators. Now lets move on to the stage following the oscillator.

THE BUFFER

The stage (or stages) between the oscillator and the final amplifier is known as an intermediate stage. Any one or a combination of the following three terms—frequency multiplier, buffer, and amplifier—can be used to describe the intermediate stage. All three terms are closely inter-related, and the one given this stage depends entirely on its function in the transmitter. When no intermediate stage is used, the oscillator output feeds directly into a "final" amplifier which, however, assumes the functions of buffing as well as amplifying and may be made to serve as a frequency multiplier also. In the following paragraphs we are going to shorten the terms to fit ham terminology; the frequency multiplier, for example, will be referred to as a "doubler" or a "tripler" or even a "quadrupler," all of which are common, everyday words which all hams recognize as indicating whether the stage multiplies the frequency two, three or four times. "Buffer-amplifier" is generally referred to as "buffer," even though it may amplify. If it is serving only as an amplifier of the fundamental frequency, it is more correctly termed a "straight" (or intermediate) amplifier; if it multiplies the fundamental two, three, four or more times, it is termed a "frequency multiplier" and is designated as a doubler, tripler, etc. Actually, this intermediate stage serves also as an "isolation" stage and is occasionally referred to as such, whether it acts as a frequency multiplier or merely as a straight amplifier. It isolates the oscillator from the following stages. By so doing, it prevents "frequency modulation" or shifting of the carrier frequency back and forth with modulation. Should this occur, the signal would not only require a wider channel in the radiation pattern, but would also distort and cause unnecessary interference to other stations. This is where the "buffer" action of the intermediate stage comes into the picture. It serves to "buff" or give the "cold shoulder" to the modulation variations in the final amplifier, so they cannot feed back into the oscillator and cause frequency instability there. If it did no more than that, the buffer would be a valuable adjunct to any phone transmitter of the amplitude modulated type. It is not so important when CW is used exclusively, but a buffer stage is most certainly desirable in any amplitude-modulated phone rig. Next, let's look at the amplifying action of the intermediate stage.

THE INTERMEDIATE STAGE AS AN AMPLIFIER

As we have previously learned, popular practice is to use an oscillator, either crystal-controlled or VFO, with a low-power-output to "drive" a following stage. Here the output of the oscillator is amplified several times and passed on either to a following stage or, in many cases, directly to the antenna. Usually, with the exception of the more elaborate, high-powered transmitters, only one intermediate stage is used between the oscillator and the final amplifier. In phone applications the intermediate stage can serve as a buffer for AM phone and, at the same time, as an amplifier of the oscillator output. The output of the intermediate amplifier is then passed on to the next stage (ordinarily the "final" amplifier) which again amplifies the signal before feeding it to the antenna. As we mentioned previously, some transmitters do not use an intermediate amplifier. Any AM phone transmitter should employ an intermediate stage for its buffing characteristics, whether it amplifies or not. An intermediate amplifier stage is seldom employed, nor is it necessary in the lower-powered transmitters devoted exclusively to CW operation. The intermediate amplifier is also dispensed with in many cases where the input power to the final amplifier does not exceed a few hundred watts. Higher-powered (500-1000 watt) CW transmitters, however, generally require more input than is supplied by the usual oscillator output, therefore intermediate amplification is required. How about a few questions on the intermediate amplifier now?

1. Used to amplify the fundamental frequency of the oscillator, an intermediate stage amplifier is known as:
   - (A) A doubler.
   - (B) A tripler.
   - (C) A quadrupler.
   - (D) A straight amplifier.
   - (E) A frequency multiplier.

ANSWER: (D)

2. An intermediate amplifier, in its "buffing" action, serves to prevent:
   - (A) The oscillator frequency from reaching the final amplifier.
   - (B) The radiation of harmonic frequencies.
   - (C) Frequency modulation.
   - (D) Overmodulation.
   - (E) Overloading of the final amplifier.

ANSWER: (C)

3. An intermediate amplifier used with an AM phone transmitter to prevent frequency modulation is called:
   - (A) A frequency doubler.
   - (B) A buffer.
   - (C) A final amplifier.
   - (D) A frequency multiplier.
   - (E) A filter.

ANSWER: (B)

Now let's discuss the third function which an intermediate stage can perform.

FREQUENCY MULTIPLICATION

The output of any oscillator, whether it be operating on its fundamental frequency or a harmonic of its fundamental, can be further increased, frequency-wise, in multiples of the fundamental frequency. This is easily accomplished; the oscillator output is fed into an intermediate amplifier whose tuning controls are adjusted to two, three, or even four times the frequency of the oscillator output. It is this higher frequency signal that is in turn passed on to the next stage. An intermediate stage operating in this manner is termed a "frequency multiplier," although its amplifying and buffing qualities are not affected. In other words, the intermediate stage can serve simultaneously in all *three* capacities; as a multiplier, an amplifier and a buffer. In using the intermediate stage for multiplying (as well as amplifying) the output of the oscillator, it is best that the multiplying stage act as no more than a frequency "doubler" although, of course, if it receives sufficient output from the oscillator, it *can* be used to triple, even quadruple or more. However, the output of the oscillator at the harmonic frequencies is less as the multiples increase. The 4th harmonic will be weaker than the 3rd, etc.

Suppose that you are using a crystal oscillator operating on a fundamental frequency of 3520 and you want to work CW in the 20-meter band. By tuning your oscillator stage to twice the fundamental frequency (7040 kc), you'll enjoy a relatively high output as 7040 represents only the *second* harmonic. By tuning the oscillator stage to the fourth harmonic (14.080 kc) you'll be all right, provided the oscillator output on the 4th harmonic is strong enough to drive or excite the next stage. Much depends on the normal output of your oscillator on the fundamental, as you will get somewhat less output on the *2nd* harmonic, even less on the 3rd, etc. Another consideration is whether you are going to use the oscillator harmonic to drive a final stage or an intermediate amplifier. The latter will require far less excitation than will a final amplifier.

Let's pause here briefly to use a few arbitrary figures to clarify this still more. Suppose that on the fundamental frequency the oscillator output is 5 watts. On the 2nd harmonic, its output drops to 3 watts, and on the 4th harmonic to 1 watt. The tube you are using in the final amplifier requires a driving power of 5 watts; on the fundamental, that is just right—your oscillator can handle it. On the 2nd harmonic, though, you are cheating the final amplifier tube by 2 watts; your transmitter will not be working at full efficiency. Tuning your oscillator to the 4th harmonic will, we'll say, drop its output another 2 watts so that it now becomes only 1 watt. Performance of your transmitter will be even more inefficient with such skimpy drive; it may not perform at all! In such a case an intermediate amplifier would be required to build up the signal at the harmonic frequency sufficiently to drive the final amplifier.

Suppose we feed the oscillator's *2nd* harmonic (7040kc) into the grid of an intermediate amplifier tube serving as both amplifier and multiplier. The 3 watts output of the oscillator on the 2nd harmonic is more than ample to drive the conventional amplifier/multiplier stage. Assume that the 3 watts *input* to the intermediate stage is doubled. The resulting output would then be 6 watts which would adequately drive the final amplifier on 7040 kcs. But, suppose you want to work on 14,080 kc and don't want to double in the final. Then let the intermediate amplifier act as a doubler by tuning its output circuit to 14,080. Suppose by so doing, we lose one watt in its output; you still have the 5 watts you need to drive the final, the latter being tuned to 14,080 which, in effect, is the "fundamental" as the antenna sees it! Now you have attained your goal; you have multiplied the frequency 3 times by using the 2nd harmonic of the final, have reduced the danger of spurious radiations and are operating the transmitter at full efficiency!

While it is entirely practical to triple the frequency right at the oscillator itself and triple again in an intermediate stage. and even *again* in an additional intermediate stage, it introduces many problems and involves many undesirable losses. The very best arrangement, of course, is to use a crystal with a fundamental frequency which will call for no more than doubling in the oscillator stage and perhaps doubling again in an intermediate stage, acting as a frequency multiplier/amplifier.

Before we leave this subject, we should answer a question which is probably in your mind by now. What about the VFO? Can frequency multiplication be accomplished when a VFO instead of a crystal oscillator is used? Most certainly! However, it isn't common practice in that the better type of VFO is capable of adjustment to *any* frequency in the amateur bands—at least from 10 through 80 meters. Many, of even more elaborate construction, cover from 2 to 160 meters! Inasmuch as this represents just about any frequency a ham could want, tunable in the VFO *without* multiplication therein, why multiply? Whatever the VFO is tuned to becomes the fundamental. On the infrequent occasions where the VFO does *not* quite reach one of the high frequencies which you wish to use, a little pencil-and-paper work, using common arithmetic, will tell you where to set your VFO dial to come up with a frequency which, even if multiplied again in an intermediate stage, will land you where you want to be. Just remember that *any* oscillator, whether crystal or VFO, will produce harmonics, and harmonics are treated exactly as if they were the fundamental when passing them on to other stages. If your head has cleared now after digesting all of the above, let's see what you can do with a few questions.

1. Using a crystal with a fundamental frequency of 3555, what frequency will result by doubling?

(A) 7110.
(B) 7155.
(C) 7175.
(D) 7150.
(E) 7135.

ANSWER: (A)

2. Which harmonic of a crystal has the greatest output?

(A) 3rd.
(B) 2nd.
(C) 4th.
(D) 1st.
(E) 5th.

ANSWER: (D)

3. What frequency crystal would you select from which to double to 28,600 kc?

(A) 7150.
(B) 3555.
(C) 14,200.
(D) 7175.
(E) 14,300.

ANSWER: (E)

Before we leave this section, we want to remind you that all of the figures which we have used herein are purely arbitrary and they take into account none of the minor losses which may occur. Therefore, an allowance of 2 or 3% should be subtracted from each in actual practice. For example, with a 5-watt input to an intermediate stage which multiplies by 2, we come out theoretically with 10 watts output. Subtract 2 or 3% from this output figure for losses in multiplying and possible other minor losses in components and circuitry. This, too, must remain a hypothetical figure in that to make an accurate calculation it would be necessary to know the type of tube used, the voltages and whether the stage is doubling, tripling, quadrupling, etc. Remember, the higher the harmonic, the greater the loss.

CHAPTER 6

RF POWER AMPLIFIERS

The purpose of the RF power amplifier is to provide sufficient amplification of the RF signal to adequately "excite" an antenna with a reasonable amount of power. By *reasonable* we mean enough power to insure satisfactory communication not only in your local area but at considerable distance, often worldwide. Through the proper choice of tubes and power supply voltage and current, the RF amplifier can boost the relatively small RF power supplied by the oscillator, intermediate amplifier, or multiplier stage, to any degree up to the maximum legal limit of one kilowatt. World-wide communications have been accomplished with much less power under the right condition—choice of frequency, time of day, consideration of existing atmospheric conditions, etc.

Frankly, we don't recommend jumping from the Novice class limit of 75 watts input directly into the "gallon" or 1000-watt classification after receiving your higher grade license, even if it is within your economic status. This, considered from the ham standpoint is "high power," and because of the higher voltages and additional technical considerations presents a number of problems which can be taken in stride by the experienced ham, but are a bit on the precarious side for the newcomer to the General or Technician classes. It's better that you begin with somewhere between 100 and 150 watts input to the final amplifier. The following discussion will be based on a power amplifier with an average figure of about 125 watts input.

SINGLE-ENDED, PARALLEL, AND PUSH-PULL OPERATION

The final amplifier is basically the same as any other type of amplifier although it may seem rather complex, when viewed in schematic form, because of the inclusion of band switches, meter

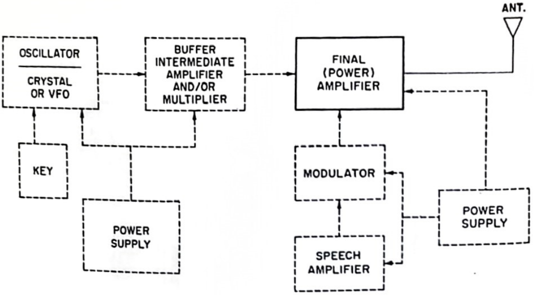


Fig. 6-1. Block diagram of a basic phone/CW transmitter.

switching arrangements, voltage regulating circuits and similar "refinements." Fig. 6-1 is a block diagram showing the relationship between the RF power amplifier and the other stages of the transmitter. A typical single-ended RF power output stage is shown in Fig. 6-2.

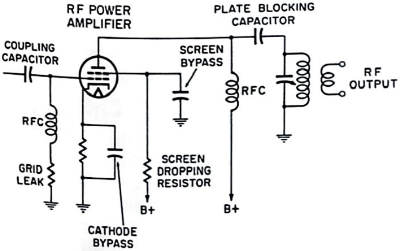


Fig. 6-2. A typical single-ended RF power output stage.

The final stage is not necessarily restricted to use of a single vacuum tube. In earlier days, two, three, even four or more were "paralleled" for greater power output. This meant that their plates, grids and filaments were all connected together, in effect creating a single tube with two, three, four or more times the electrical capability than that of a single tube. This was in the days when transmitting tubes were rather limited in their power-handling capability. The earliest tubes were rated at about 5 watts output; by paralleling four, a theoretical increase of four times in power output, or 20 watts, was obtained. Later, 50-watt tubes made their appearance; two in parallel resulted in a theoretical 100 watts output. Next, 250-watt tubes; again, two in parallel produced a 500 watt output. Four (if you could afford it!) gave you the legal maximum of one kilowatt.

Later developments resulted in the use of two tubes connected in a "push-pull" arrangement. To put it simply, in this type of circuit the tubes co-operate with each other. One "tugs" while the other "shoves" . . . they alternate this action. The push-pull circuit overcomes a number of disadvantages that occur in straight parallel operation. For example, spurious radiation and unwanted harmonics are more attenuated. Also, the electrical balance between tubes becomes less important; in parallel operation, a "weak" tube has a tendency to pull the stronger one down, and the result is about the equivalent of two weak tubes. Tubes connected in parallel require rather close "matching" of their electrical characteristics to deliver best performance. There is one advantage of parallel tube operation. The same amount of grid drive (input wattage) required for a single tube will operate two in parallel. In a push-pull circuit the grid drive must be double that required for a single tube.

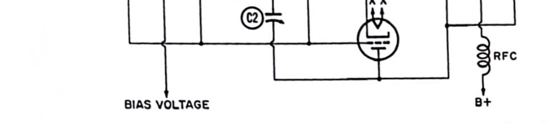


Fig. 6-3. A push-pull RF power amplifier circuit using neutralized triodes.

One type of push-pull circuit is shown in Fig. 6-3. Neutralized triodes are used in this circuit. (Neutralization will be discussed shortly.) Sometimes a combination parallel/push-pull arrangement is used. Here, two pairs of tubes are connected in parallel. Each pair is then considered as a single tube and the two are arranged in a push-pull circuit. Push-pull circuits are found not only in RF power amplifiers but often in audio amplifiers and in intermediate stages of a transmitter as well.

PARASITIC OSCILLATION

Since the output of the final RF amplifier feeds directly into the antenna system, its only logical that this stage above all must be free of unwanted harmonics and other spurious signals. Occasionally you may find a power amplifier that will go off on a tangent and act as an oscillator all by itself. At what frequency is anybody's guess. It could oscillate in the same ham band to which the circuit constants of the amplifier are adjusted, or it could be w-a-y out of bounds and oscillate at a frequency that would cause interference with commercial, military, or other ham bands. Oscillations of this type are known as "spurious radiation," or as "parasitic" or unwanted oscillations. These parasitics are definitely not desirable, and they must be eliminated or at least reduced.

Neutralization of tube capacities in the power amplifier, and often in the intermediate amplifier as well, is perhaps the most effective step we can take toward this end. Before going into a discussion of neutralization, however, let's pause briefly to look at "parasitic chokes." This choke is constructed of nothing more than a few turns of relatively heavy wire . . . say about #14 . . . wound on a resistor or on a ceramic core. Circuitwise this choke is inserted in series with the plate cap (or plate terminal) lead to the final amplifier tube. Such a simple device will not *guarantee* that spurious oscillations will not develop, but nine times out of ten it *will* insure that whatever parasitics are produced won't get much farther than the choke itself. Next we'll discuss the presence of unwanted harmonics in the final amplifier. But first let's try a few questions on final RF amplifiers and determine whether or not the previous sentences and paragraphs have made an impression.

1. A "final" power amplifier in a radio transmitter serves to:

   (A) Produce a signal of greater strength as radiated by the antenna.
   (B) Suppress harmonic radiation at undesired frequencies.
   (C) Take advantage of all harmonics generated by an oscillator.
   (D) Amplify the parasitic oscillations generated in the final amp.
   (E) Intensify the signal radiation in a given direction.

ANSWER: (A)

(Careful here; proper circuitry and adjustment *could* make (B) a good answer, but if the question (and answers) come to you as above, stick with (A) as the *correct* answer.)

2. The final or power amplifier which feeds the radiating system, receives its initial power or excitation from:

(A) The oscillator.
(B) The DC power supply.
(C) The preceding stage.
(D) The household AC circuits.
(E) Its own power supply source.

ANSWER: (C)

(Careful again; the oscillator could conceivably be the preceding stage, but as long as a "preceding stage" appears as a possible answer, use answer (C). It *could* represent the oscillator but it could *also* represent an intermediate amplifier or multiplier stage).

3. In a parallel connection of vacuum tubes in a power amplifier, how are the plates and grids of individual tubes connected?

(A) In series.
(B) Isolated—no interconnection.
(C) To separate excitation sources.
(D) To separate power supplies.
(E) In parallel.

ANSWER: (E)

4. Push-pull operation of vacuum tubes is restricted only to:

(A) Audio-frequency applications.
(B) Oscillator circuits.
(C) Frequency multiplier circuits.
(D) No restriction; may be used anywhere.
(E) Intermediate amplification circuits.

ANSWER: (D)

5. Parasitic oscillations are reduced or eliminated by:

(A) A neutralizing capacity.
(B) Proper adjustment of final amplifier components.
(C) A parasitic choke.
(D) A filter system.
(E) A by-pass condenser.

ANSWER: (C)

Do you have it now? If you're still not sure of your answers, go back over the preceding material once again. If you *were* able to answer these questions, you're ready to proceed to the next subject.

NEUTRALIZATION

Neutralization can be defined as any process that balances out or prevents an undesirable effect. Here, the undesirable effect is self-oscillation within the RF power output stage. Practically all final amplifier stages that employ triode tubes require neutralization. The tendency toward self-oscillation in a tetrode or pentode output stage is much much less, but here also you may find neutralization used as an additional precaution.

Basically an oscillator circuit is nothing more than an amplifier designed so that a portion of the signal in the plate circuit is fed back to the grid in the proper phase. When this condition exists the stage goes into oscillation. Here is a good example; you've undoubtedly heard the high-pitched squeal that comes from a public address amplifier when the gain is adjusted too high and the microphone is facing the speaker. Here, the sound coming from the speaker is feeding back into the microphone (from the output to the input). When the conditions are right (sufficient volume, phasing, etc.), the amplifier goes into oscillation. This occurs at an audio rate and can be heard. Oscillations within the final RF amplifier cannot, but are much more serious —from a legal standpoint, that is.

You're probably wondering how the feedback occurs in the final RF amplifier stage. First of all a certain amount of capacity exists between the inner elements of any vacuum tube. In a triode tube the amount of capacity between the grid and plate (input and output of the tube) is such that feedback can occur between these elements via the grid-to-plate capacitance. Thus, the tube goes into self-oscillation. This can result in the radiation of a signal whose frequency is far removed from the amateur band.

A screen grid (tetrode or pentode) tube is far less prone to self-oscillation because the screen grid, which is located between the control grid and the plate, reduces the feedback path (the capacity between grid and plate) and thus isolates these elements to some degree. The addition of a suppressor grid discourages feedback even more.

There is no way to change the *mechanical* relationship between the internal plate and grid of a vacuum tube to provide various values of capacity. Therefore we have to take an *electrical* approach to this problem. Our first consideration is to recognize the fact that we don't want this internal capacity between the grid and plate, so some means of "swamping" it out must be used. The practical solution to this problem is "neutralization." This is a good descriptive term since it states exactly what we do—"neutralize" or swamp out this undesirable capacity. At present there are two accepted methods for accomplishing this.

First, an *external* means of equalizing and thereby "neutralizing" this undesirable effect (inter-electrode capacity within the tube) appeared in the early 1920's when vacuum tubes were really beginning to "catch on." Parasitic oscillations at odd-ball frequencies were giving more than one headache to the average ham. It didn't take long to realize that the final RF amplifier stage was the source of the trouble. After a bit of experimenting and analyzing by interested parties, the parasitic choke came into being. This was a blessed relief; it held down and in many cases even completely eliminated the radiation of these spurious, parasitic oscillations. A short time later it was found that the spurious oscillations themselves, produced within the RF power amplifier, could be eliminated by using a method known as "neutralization." This method involves "swamping out" or balancing of the inter-electrode capacity of vacuum tubes (the initial source of such unwanted radiation). Neutralization is achieved by matching capacity for capacity—the initial capacity existing between the plate and grid of a vacuum tube balanced against the external capacity which could be applied to swamp it out. Take, for example, a hydraulic analogy. Suppose two one-gallon containers are connected with a short length of pipe With both containers sitting at the same base level pour water into each. Fill one container full and the other only half full. What happens? In a matter of seconds the water runs through the connecting pipe and the level in both containers equalizes. Electrically, the same thing happens in the final amplifier tube(s). Put a variable capacitor of the proper value across the grid and plate contacts, and you can find an adjustment point which will equalize the *external* capacity with the *internal* capacity of the tube. This results in a balancing out or swamping out of the undesired capacity in the circuit! The proper setting for the *external* (variable) capacitor can be determined from the milliammeter of the transmitter. The ultimate desired adjustment will be that which, with the final amplifier plate voltage disconnected, will show no (or at most a very minimum) deflection of the *grid* meter, when the tuning circuits of the final amplifier plate circuit are tuned through the resonant point for the frequency for which the circuit has been set up. Refer to the RF power output stage in Fig. 6-3. Capacitors C1 and C2 are the neutralizing capacitors in this circuit.

That, in a nut shell, is "neutralization" and basically all you'll need to know about it for the FCC exam. For all practical purposes, neutralization is a method for equalizing, balancing, or swamping, the *internal* capacity of a tube so that it no longer exists theoretically. We say "theoretically" because a small amount of capacitance may remain, and probably will, through connecting leads and otherwise, but of such an insignificant value that it will be negligible. Are you ready for some questions on the subject? Let's see.

1. The object in neutralizing an RF amplifier is to:
   - (A) Increase the harmonic output.
   - (B) Prevent self-oscillation.
   - (C) Assist generation of harmonic frequencies.
   - (D) Increase the amplifier output.
   - (E) Reduce the voltage and current demand of the amplifier tube(s).

   ANSWER: (B)

2. In what stage of a transmitter is a high harmonic output least desirable?
   - (A) Oscillator.
   - (B) Final RF amplifier.
   - (C) Intermediate amplifier.
   - (D) Speech amplifier.
   - (E) Modulator.

   ANSWER: (B)

3. Neutralization of an RF amplifier, as described in preceding paragraphs, is accomplished by:
   - (A) Adding external capacity.
   - (B) Adjustment of amplifier tuning circuits.
   - (C) Reducing grid excitation power to the amplifier.
   - (D) Increasing amplifier tube voltages.
   - (E) Decreasing amplifier plate current.

   ANSWER: (A)

4. Parasitic oscillation, as distinguished from generation of harmonic frequencies, are generally set up in the:
   - (A) Intermediate amplifier stage.
   - (B) Oscillator stage.
   - (C) Final amplifier.
   - (D) Audio system.
   - (E) Power supply.

   ANSWER: (C)

5. Insurance against radiation of harmonic frequencies of the oscillator fundamental is by:
   - (A) A parasitic choke.
   - (B) A radio frequency choke coil in the amplifier input.
   - (C) Neutralization of intermediate and final amplifier stages.
   - (D) Reduced power input to the final amplifier.
   - (E) Increasing output of the oscillator stage.

   ANSWER: (C)

6. What basic advantage does a screen-grid tube used as an RF power amplifier have over a triode with the same output capabilities?
   - (A) Less plate voltage is required.
   - (B) Less filament voltage is needed.
   - (C) No neutralization is required.
   - (D) Less power is dissipated by the plate.
   - (E) No suppressor grid is needed.

   ANSWER: (C)

7. What advantage does a push-pull RF power amplifier stage have over a single-ended stage of the same power?

   (A) Less grid drive is required.
   (B) Better harmonic suppression and more complete neutralization is obtained.
   (C) Less current is required from the power supply.
   (D) Only one filament transformer is needed.
   (E) Better voltage regulation is obtained.

ANSWER: (B)

For purposes of your examination for the General license, we need not expand this subject any further, except to say that the two popular and accepted methods of preventing self-oscillation in the RF output stage are: to use (1) an external neutralizing capacity in a triode circuit, or (2) tetrode or pentode tubes, which normally require no neutralization. You will find one or the other of these methods used in the majority of commercial transmitters currently on the market.

THE FINAL AMPLIFIER OUTPUT

In dealing with the final RF amplifier you will be concerned with the RF signal fed to the grid of the final stage, since the latter will appear greatly amplified at the output. However, the plate power input, among other things, determines the amount of amplification provided by the stage.

The output power will always be less than the plate power input due to losses in the tube. This loss should not be confused with the RF signal fed to the grid of the final stage, since the latter will appear greatly amplified at the output. However, the plate power input, among other things, determines the amount of amplification provided by the stage.

An average RF power amplifier is about 70% efficient. This means that a plate power input of 100 watts will result in approximately 70 watts output. Some transmitters have finals that are only 50% efficient, however, 70% is considered average. The maximum plate power input allowed a Technician, Conditional, or General licensee is 1000 watts. With a final stage efficiency of 70% this would mean that approximately 700 watts of RF power would be delivered to the antenna, disregarding the various RF losses introduced by impedance mismatch, etc.

After the desired RF signal is sufficiently amplified, our next concern is delivering it to the antenna and hence into the atmosphere as a radio communication signal. It may be radiated as a continuous wave which we break in small pieces through the use of a telegraph key, or it may vary up and down in conformity with the phonetics of human speech.

There are many methods of coupling the RF signal to the antenna. We know (or should, by now) that the "tank coils," or the final amplifier plate inductance contains the RF energy to be fed to the antenna system. The next problem is to get the RF *out* of the power amplifier circuit and upstairs to the antenna where it can do some good.

The radiating system can take many forms. It may be a simple, single piece of wire of random length or an elegant rotary beam atop a high tower. The main thing is to deliver the radio frequency energy from the final amplifier tank coil to the antenna. How far the signals travel and how effective they are is pretty much up to the radiation system.

In dealing with antennas you'll encounter such terms as "impedance matching," "transmission lines," "standing wave ratios," etc., all of which will no doubt introduce confusion in your mind if your background is still a bit on the skimpy side, insofar as radio and electronics are concerned. Don't let it faze you. The FCC examination will have few, if any, questions on antennas. One important point to remember in regard to the antenna, however, is that the maximum transfer of RF energy from the "tank" or final amplifier coil to the radiating system occurs when the output impedance of the final amplifier matches the antenna impedance. Many transmitters employ a "pi" section antenna coupling arrangement. Boiled down this merely means that the final amplifier coil and variable capacitor serve some-

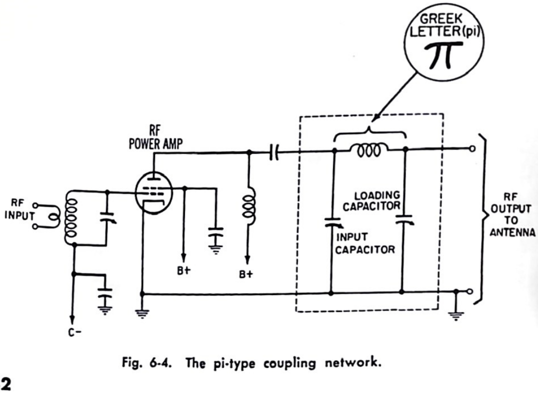


Fig. 6-4. The pi-type coupling network.

what in a dual capacity; an additional variable capacitor on the *output* (to antenna) side of the coil enables you to tune the antenna circuit to resonate with the final amplifier output frequency. An RF power amplifier using a pi-type coupling network (in dotted lines) is shown in Fig. 6-4. The designation "pi" was adopted for this circuit because of its similarity to the Greek letter π (pi). Another method, known as link coupling, is also quite popular. An RF power amplifier using this arrangement is shown in Fig. 6-5. Familiarize yourself with these circuits; you may have to identify or even sketch them.

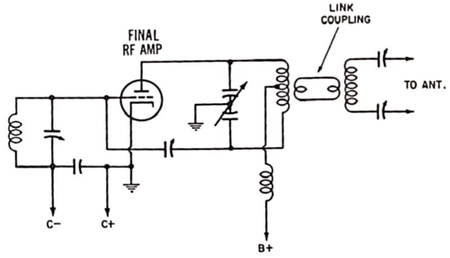


Fig. 6-5. A basic RF-output stage using link coupling.

Some hams prefer to use an "antenna coupler" or, as it is sometimes termed, an "antenna tuner" in hopes that they will thereby realize the optimum in maximum radiation. If you want to tackle all of the intricacies of antenna systems, feeder methods, etc., you will find many books devoted entirely to this subject. For FCC examination purposes, you won't have the least need to know anything about what happens to your signals after they reach the final amplifier tank coil. "Impedance matching," proper (?) "feeder" systems, intricate "coupling" devices, and similar schemes tend only to confuse the newcomer; at the same time they make sense to the old-timer with an electronic background who wants to accomplish with maybe 50 watts what he formerly did with 100 on a hit or miss basis.

Television Interference (TVI)

You won't find, in your formal FCC examination, very much of anything which has to do with *radiating* your signal on the air. Their concern is only with what effect, interference-wise, such radiation may have with other radio services. By confinement to certain specified bands of radio frequencies, the FCC rightly feels that the amateur emissions into space should not be a source of disturbance to other radio services operating in areas alloted to them in the radio frequency spectrum. It is, therefore, contingent on us as radio hams to see that our own individual radiations are *not* such as will cause interference and annoyance to others using the air space.

An electrostatic shield, better known as a Faraday shield, is often used in a coupling network to reduce undesirable harmonic transfer between the RF amplifier and the antenna system. Fig. 6-6 shows a typical RF coupling circuit using such a shield. If this were not used, capacity coupling existing between coils L1 and L2 could result in the transfer of undesirable harmonics and thus cause radiation of signals that could interfere with other stations.

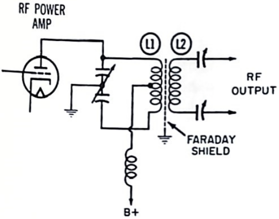


Fig. 6-6. A typical RF coupling network using a Faraday shield.

An amateur transmitter can and often does cause interference with neighboring television receivers on one or more channels, even though the transmitter is properly adjusted. It is also possible that the TV receiver experiencing the difficulty is itself at fault. You should first determine, of course, whether it is your emissions which are causing the trouble or whether the TV receiver is inadequately shielded, antiquated, or both. It is likely that installation of a high-pass filter at the antenna input terminals of the TV receiver will eliminate the difficulty, or at least minimize it to a point where it will be negligible. A high-pass filter serves to prevent any radio frequency energy *below* the cut-off frequency from effecting the receiver.

On the other hand, if it is determined that it is *your* radiation causing the interference, then a *low-pass* filter installed at the transmitter output should prove effective. Such a filter will not affect the normal output on the frequencies you use, but it will greatly reduce the RF energy *above* its cut-off frequency, thereby greatly attenuating any harmonic radiation that could cause interference in TV channels.

Determination of where the fault lies should be worked out between you and the complainant, with the assistance of your local radio club or TV repairman if need be. Suitable filters are readily available and are not expensive; just remember (you'll probably be asked a question or two on this subject) that it will take a *high*-pass filter at the receiver antenna input or a *low*-pass filter at the output of the transmitter; in aggravated cases, perhaps both.

In earlier days, radio hams were blamed for just about anything which caused such interference with the then-popular (early 1920's) reception of broadcast music and entertainment. Flashing lights from advertising signs, automobile ignition systems, faulty house wiring, defective appliances—all were labeled as interference from "that radio ham down the street." Certainly, technical investigations bore out the fact that the amateur was to blame in only a very small percentage of such interference complaints. The same has been true since the advent of television. "Snow" on the screen, "ghosts," and other distorted images are still being blamed on the radio ham by a large proportion of the public. Unjust, it's true, but it does put it squarely up to the radio amateur to make certain that *his* radio frequency emissions are clean; that they cannot be responsible for the various idiosyncrasies which the relatively new art of television has developed. And to you as a radio ham, particularly as a newcomer to the General field which gives you much broader leeway in which to spread your radio frequency emission around, recognition of this responsibility is of even greater importance. Suppose we now try our skill at answering a few questions on the final amplifier.

1. After you have supplied the proper excitation to the final amplifier and the latter is producing radio frequency emission at the predetermined frequency, it is:

   (A) Fed to an antenna (radiating system) from which it is projected into space.
   (B) Canceled out by a neutralizing process.
   (C) Used to feed an additional amplifier stage.
   (D) Allowed to be absorbed by shielding and/or other metallic objects in its electrical field.
   (E) Multiplied into a frequency which it is desired to radiate.

   ANSWER: (A)

2. If a ham transmitter has a tendency to break into oscillation at some frequency, perhaps not even remotely related harmonically to the oscillator fundamental frequency, by what term is such oscillation known?

(A) A harmonic.
(B) The fundamental frequency.
(C) A parasitic oscillation.
(D) A multiple of the fundamental frequency.
(E) Half the fundamental frequency.

ANSWER: (C)

3. If unwanted radiation from the final amplifier occurs at twice, three times, four times or some similar multiple of the fundamental frequency, it is known as a:

(A) Parasitic oscillation.
(B) Spurious oscillation.
(C) Audio frequency oscillation.
(D) Harmonic oscillation.
(E) Beat frequency oscillation.

ANSWER: (D)

4. The plate power input of the final RF amplifier is determined by:

(A) Subtracting the plate current from the plate voltage.
(B) Multiplying the plate voltage by the plate current.
(C) Adding the plate voltage and plate current.
(D) Multiplying the plate voltage by the plate current, and subtracting the grid input power.
(E) Subtracting the grid voltage from plate voltage.

ANSWER: (B)

5. What output circuit conditions provide optimum output from an RF amplifier?

(A) Equal plate current and plate voltage values.
(B) When two capacitors of equal value are connected in series with the transmission line.
(C) When a pi-type network is designed to reject the fundamental frequency.
(D) When the output circuit impedance matches the rated tube load impedance.
(E) When the plate current reaches minimum, and the plate voltage, maximum.

ANSWER: (D)

6. What is a typical efficiency figure for the final stage of an average AM transmitter?

(A) 100%
(B) 25%
(C) 50%
(D) 40%
(E) 70%

ANSWER: (E)

7. What is the plate current indication as the plate tank circuit of an RF power amplifier is tuned off-resonance?

(A) Decreased plate current.
(B) A sharp increase in plate current.
(C) No change in plate current.
(D) Plate current is halved.
(E) Zero plate current.

ANSWER: (B)

(You should have remembered the answer to this question from your Novice studies. It's included here for those with little or no previous experience with transmitter adjustments.)

8. The Faraday shield used in a coupling network between the RF power amplifier and the antenna system serves to:
   - (A) Reduce the plate resistance of the final amplifier.
   - (B) Increase the amount of power fed to the antenna.
   - (C) Eliminate the need for external neutralization of the RF output stage.
   - (D) Reduce undesirable harmonic transfer between the RF amplifier and the antenna system.
   - (E) Provide a better impedance match between the antenna system and the RF output stage.

ANSWER: (D)

9. In the event television interference is caused by an amateur station, where should a low-pass filter be connected?
   - (A) At the antenna input terminals of the affected TV receiver.
   - (B) Between the oscillator and the intermediate amplifier stage of the transmitter.
   - (C) At the wall plug.
   - (D) At the transmitter output.
   - (E) Between the intermediate amplifier and RF power output stages.

ANSWER: (D)

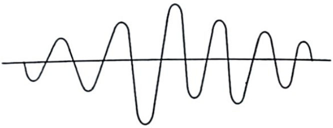
10. Where would a high-pass filter be connected to reduce television interference caused by an amateur station?
    - (A) In series with the antenna lead at the transmitter output.
    - (B) At the input terminals of the affected television receiver.
    - (C) Across the power supply terminals.
    - (D) Across the antenna output connector on the transmitter.
    - (E) Between the transmitter oscillator and doubler stage.

ANSWER: (B)

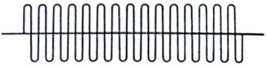
CHAPTER 7

MODULATION SYSTEMS

By themselves, the audio frequencies from a microphone (Fig. 7-1A) are not capable of being radiated from an antenna into free space. The reason, of course, is because of the low frequency of these signals. The signal produced by the oscillator in the transmitter (Fig. 7-1B), however, varies at a much higher frequency and is capable of being radiated. Thus, the output of the oscillator is termed an RF (radio frequency) signal. Since the audio signal is the one needed at the receiver (for radiotelephone reception), some means must be provided to carry it through space from the transmitter to the receiver. This is the purpose of the RF signal, and why it is termed the carrier. After



(A) The audio-frequency signal.

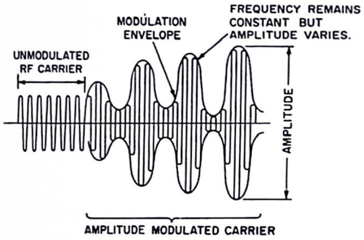


(B) The RF carrier signal.

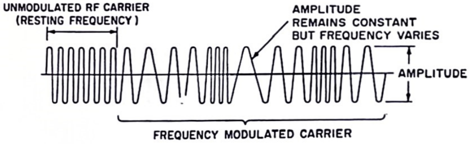
Fig. 7-1. The signals required for radiotelephone communications.

the signal from the microphone has been sufficiently amplified, it is used to modulate (vary) the RF carrier of the final amplifier in accordance with the audio signal.

In ham radio as in commercial radio applications, there are two methods in most common use. These are "amplitude modulation" and "frequency modulation," more commonly referred to as "AM" and "FM" respectively. When the *amplitude* of the radio frequency output is caused to vary (Fig. 7-2A), the transmitter is *amplitude* modulated; when the *frequency* of the RF output is varied (Fig. 7-2B), it is "frequency modulated." Relatively recently, what is known as "single sideband" modulation has been rapidly gaining in favor with radio amateurs. While this method has definite advantages over both AM and FM, at this writing it has not appeared in the Federal amateur examinations —at least not to an appreciable extent.


FREQUENCY REMAINS CONSTANT BUT AMPLITUDE VARIES.
MODULATION ENVELOPE
UNMODULATED RF CARRIER
AMPLITUDE
AMPLITUDE MODULATED CARRIER

(A) Amplitude modulation.


UNMODULATED RF CARRIER (RESTING FREQUENCY)
AMPLITUDE REMAINS CONSTANT BUT FREQUENCY VARIES
AMPLITUDE
FREQUENCY MODULATED CARRIER

(B) Frequency modulation.

Fig. 7-2. Methods of modulating the RF carrier.

Any radio system depends first upon a "carrier," which is the RF output of the transmitter. During CW (continuous waves) or radiotelegraph operation, the unmodulated carrier is interrupted by means of the telegraph key, and both its amplitude and frequency remain constant. In radiotelephony the carrier remains on constantly during transmissions and either its amplitude or its frequency is modulated by a voice signal. In addition to the carrier frequency, which is determined by the oscillator and/or frequency-multiplying circuits of the radio transmitter, we also must deal with audio frequencies which, superimposed on the carrier, constitute modulation thereof. These audio frequencies vary from about 250 cycles per second (cps) to 3000-4000 in normal voice transmission.

Because voice, contrary to a CW carrier wave, has a comparatively wide range of inflections, a suitable range from the zero level of the carrier must be provided. Suppose we take 3500 cycles as an arbitrary figure here. Two *more* frequencies are thereby generated; one at 3500 cps *higher* than the carrier frequency, the other 3500 cps *lower*. Adding the two we come up with 7000 cps; reduced to kilocycles, a bandwidth of 7 kc. So, it is rather evident that if our radiotelephone transmission will occupy 7 whole kilocycles in the spectrum, it would require at least that frequency separation between the carrier waves of two phone stations to eliminate or greatly minimize interference between the two! There would be room in that area for from possibly 10 to 12 CW stations to operate with little or no interference to each other!

These additional frequencies which take up this spread are known as "sidebands," without which you would have no modulation. However, by eliminating one of them, which has been an accomplishment of circuit designers in recent years, only *half* the bandwidth (3.5 kc) is required for intelligent speech transmission! In effect, then, *two* radio telephone stations could operate, free from interference with each other, where only *one* is possible otherwise. This readily explains the popular current trend of phone amateurs to convert to the "single sideband" method.

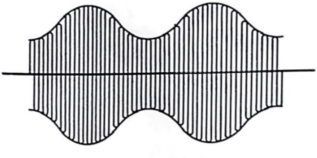
PURPOSE OF A MODULATOR

The load for our most common vehicle, the automobile, is normally that of a man himself who simply steps into the interior. But with inanimate objects, such as cases of canned food, mechanical fork lift trucks are often used to place them on the vehicle. Similarly, some apparatus—an electronic circuit—is required to load a radio-frequency wave. As the radio-frequency wave is an abstract thing that does not excite any of our five senses, its "load" must also be an abstract thing, like another electromotive force wave. And, just as a weight placed on a mechanical vehicle affects its speed or its power, the "load" on a radio-frequency wave can alter either the amplitude or the frequency of the wave. This "load" of the radio-frequency wave is commonly an electromotive force wave that varies as a sound wave, or as pulses giving some form of intelligence.

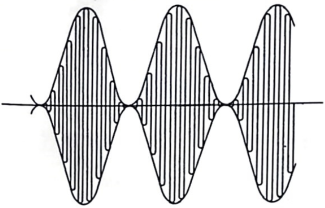
With this intelligence the radio-frequency wave is said to be changed, or *modulated*, and the electronic circuit that combines the intelligence and the radio-frequency wave is a *modulator*. So, the purpose of a modulator is to combine the variations of a wave representing intelligence, with a radio-frequency carrier wave. When the modulator causes the radio-frequency carrier wave to vary in *amplitude*, the result is known as *amplitude modulation*. *Frequency modulation* occurs when the modulator causes the carrier wave to deviate from its normal *frequency*.

METHODS OF MODULATING THE RF SIGNAL

With the exception of frequency modulation (FM), we have briefly covered AM and SSB (single sideband) as modulation systems now in popular favor. FM, while not in as common use as the above two, has been and is being used by many amateurs. In any modulation system, FCC restricts the *percentage* of such modulation to 100. To exceed that figure not only makes the transmission illegal but results in what is termed "over-modulation," distorting the speech, widening the bandwidth, and creating additional interference. The effect of modulation on an AM carrier can be more clearly seen in Fig. 7-3. In Fig. 7-3A the



(A) 50% modulation.



(B) 100% modulation.

Fig. 7-3. Effect of the modulation strength on the RF carrier.

signal has been modulated 50%; in Fig. 7-3B, 100%. Overmodulation causes the voice to climb out of bounds and results in "splatter," as it is familiarly termed in ham circles. It is not necessary to adjust the modulation percentage to *exactly* 100%; a percentage as low as 85 will produce very intelligible speech. 100% can be termed "hi-fi," and results in the most faithful speech reproduction, but for conversational purposes is considerably more than necessary and *could* result in going overboard sufficiently to draw an FCC citation. If you have the know-how and the equipment (an oscilloscope is about the most desirable device for this purpose, although comparatively few hams have one), set your modulation percentage at about 95, which will give you some legal leeway and get you many complimentary reports on your voice quality.

While, insofar as the ham radio field is concerned, AM, FM, and SSB modulation systems are in the forefront, it must not be thought that these comprise the *only* modulation systems possible. What we are primarily interested in is knowledge of the ways and means by which to achieve either AM or FM, so you can intelligently answer the questions which appear on your examination sheet.

Plate Modulation

Plate modulation is perhaps the most popular method used with AM ham equipment. This method is entirely capable of producing 100% modulation which ensures maximum distance coverage, inasmuch as 100% modulation results in maximum distortionless power in the sidebands. To realize this percentage and to take full advantage of available RF power, the modulation system must be capable of supplying sufficient audio power. The rule of thumb is that, to achieve 100% modulation, the audio system should be capable of delivering one half as much power as the radio frequency final amplifier. In our hypothetical transmitter, running 112 watts *output*, an audio power of 56 watts would be required to realize 100% modulation. Add this power to the 112 watts of *radio* frequency, and you turn up with 168 watts on the air! Don't be fooled here though; this is assuming an over-all efficiency of 100%, which is unattainable. If we go back to what we originally considered a pretty fair efficiency of 70% over-all, we still turn up with a good husky signal.

To realize greatest efficiency in plate modulation, the modulation transformer must match the impedance of the modulator tubes to the impedance of the RF amplifier. In addition, sufficiently heavy wire must be used on the primary winding of the modulation transformer to carry the modulator tubes' plate current. Likewise, its secondary winding should have sufficient capacity to handle the RF amplifier plate current.

Modulation, particularly with respect to transmitter powers of 150 watts input or higher, goes a little farther than simply a tube and a modulation transformer. The relatively weak output from the microphone is insufficient to actuate the final radio frequency amplifier with enough audio to constitute intelligible speech; in fact, if such a method were attempted in plate modulation, the microphone would probably blow up in your face before you could get an intelligible modulated signal on the air! Just like the radio frequency circuits for a straight CW transmitter, you've got to build the power up gradually through amplification until it has reached a level sufficient to produce the final power output you are seeking. Remember the RF oscillator? Its output was insufficient to actuate the final amplifier running at 150 watts input. We had to introduce one or more intermediate amplifying stages between the oscillator output and the final amplifier input circuits. The same is true for the audio signal. The voice entering the microphone generates a small audio voltage which must be amplified sufficiently to drive the modulator. Fig. 7-4 shows a basic block diagram of an audio system.

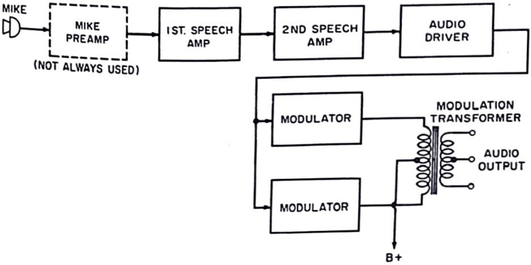


Fig. 7-4. Block diagram of a basic audio system for a transmitter.

Although a mike preamp is sometimes used, suppose we consider the initial audio stage as the first speech amplifier. The voice output from the microphone is applied to the grid. Here, the signal is amplified and fed to a second speech amplifier. (In some of the lower-powered equipment only one speech amplifier is used). The output of the second speech amplifier feeds into the "driver" stage. The output of the driver is transformer-coupled into the modulator stage, which may use either a single-ended or push-pull arrangement. The output of the modulator in turn is inductively coupled into the DC plate circuit of the final RF amplifier, where it serves to modulate the RF output in accordance with the inflections of the spoken word. This briefly describes one system of plate-modulated AM. There are, of course, many variations of this method, but this will serve to illustrate a plate-modulated AM system to an extent which will enable you to handle the few questions you may receive on this subject. It is probably obvious to you that such a modulation system closely parallels your radio frequency equipment sequence: the microphone generates the initial audio voltage and can be likened to the RF oscillator; the modulation driver stage is comparable to the intermediate RF amplifiers and/or frequency multipliers; and the modulator stage is like the final RF power amplifier.

Plate and Screen Modulation

Where a tetrode tube is used as the final amplifier, both the plate and the screen voltages must be modulated, otherwise the modulation system will be very inefficient because the percentage of modulation to audio power input will be very low. The plate alone can be modulated, provided that the screen DC supply voltage is first passed through an audio choke. Likewise, the screen alone can be modulated, but either method will result in a less linear modulation characteristic. Most satisfactory results are obtained by modulating *both* the plate and the screen.

Grid Modulation

Grid modulation is the most economical method, as it requires so little audio power. For the hypothetical transmitter which we have previously used as an illustration of various points, only about 3 watts output from a simple speech amplifier stage (eliminating the need for the driver and modulator stages), is ample for satisfactory voice transmission. The output of the speech amplifier is coupled into the *grid* rather than the plate circuit of the final RF tube. Grid modulation calls for more careful adjustment of the bias supply of the RF amplifier as well as the plate supply of the preceding RF amplifier. Careful regulation here will do much to minimize the distortion which would result in the modulation circuits otherwise.

Other Modulation Methods

While the brief descriptions of the more common modulation methods we have just described do not by any means encompass all of the usable means of modulating a radio frequency carrier, you will find them sufficient for your examination requirements.

A number of other methods, although not enjoying much popularity in amateur circles, are cathode modulation, where, by modulating in the cathode circuit, *both* the plate and grid of the tube (final RF amplifier) are modulated. Modulation may also be accomplished in the suppressor grid of pentode-type tubes. Pulse modulation is employed to some extent in commercial applications but has little place in the amateur field, as are a number of other types in limited commercial and military use.

Frequency Modulation

Frequency modulation, unlike AM, creates many sidebands. Up to about the tenth harmonic, an upper and a lower sideband for each modulating frequency and each harmonic of each modulating frequency exist. FM has attained some measure of popularity in amateur circles, although it has been somewhat restricted in that an FCC provision prohibits its use at the lower amateur frequencies *unless* it is what is termed "narrow-band frequency modulation." Since so many sidebands are generated, the bandwidth required is far too wide for practical use without causing undue interference with other amateur stations. FM, however, is becoming quite popular in the 6- and 2-meter amateur bands, where space in the frequency spectrum isn't too much of a problem. Whereas FM broadcast stations, transmitting high quality musical programs, occupy bandwidths as much as 200 kilocycles wide, the modest voice requirements of amateurs do not require nearly so wide a spread. Since the bandwidth required by commercial FM broadcast stations is quite wide, it is obvious why there is a limit to the number of stations which may be so licensed. On the other hand, narrow-band frequency modulation (NBFM), permitting the amateur to enjoy phone privileges in certain portions of several bands, is allowable *provided* the bandwidth does not exceed certain limits.

Single-Sideband Modulation

Although single sideband (SSB) is becoming more and more popular, you will receive few, if any, questions regarding this subject on your FCC examination. Suppose, however, we make a quick run-down as a matter of information; it should assist you in a better understanding of other modulation systems. As we mentioned earlier, by elimination of *one* sideband in radiotelephone transmission, only half the bandwidth in the RF spectrum is required, making is possible for *two* stations to operate where only one could previously do so. Elimination of one sideband, leaving the other to carry the intelligence, is entirely feasible and practical. Such elimination is accomplished by means of parallel resonant filters. The unwanted sideband is attenuated by the filter circuit leaving only the desired sideband to be amplified. As a matter of interest, television transmission involves a form of single-sideband transmission. However, it is somewhat in variance with SSB as known and used by hams; the TV station transmits one *complete* sideband and uses only a part of the other. This is known as "vestigial sideband transmission" with which you need not be concerned as an amateur.

Now, after a few questions on the foregoing, we shall take up some miscellaneous points having to do with various details of radiotelephone operation on which you may be questioned.

1. When the amplitude of the radio frequency output is varied by a modulation system, it is known as:

   (A) Frequency modulation.
   (B) Single-sideband modulation.
   (C) Amplitude modulation.
   (D) Phase modulation.
   (E) Pulse modulation.

ANSWER: (C)

2. Frequency modulation is accomplished by varying the:

   (A) Amplitude of the RF output.
   (B) Final amplifier plate power input.
   (C) Final amplifier grid current.
   (D) Frequency of the RF output.
   (E) Final amplifier grid current.

ANSWER: (D)

3. Single-sideband modulation employs how many sidebands?

   (A) One
   (B) Two.
   (C) Multiple.
   (D) None.
   (E) Four.

ANSWER: (A)

4. When audio output power is injected into the plate circuit of an RF amplifier, the method is known as:

   (A) Grid modulation.
   (B) Plate modulation.
   (C) Screen modulation.
   (D) Cathode modulation.
   (E) Plate and screen modulation.

ANSWER: (B)

5. Grid modulation is a method which applies the audio output power to what circuit of the RF amplifier?

   (A) Screen.
   (B) Plate.
   (C) Cathode.
   (D) Screen grid.
   (E) Grid.

ANSWER: (E)

6. What modulation method is most demanding of audio frequency power?

(A) Screen.
(B) Grid.
(C) Plate.
(D) Cathode.
(E) Suppressor grid.

ANSWER: (C)

7. Which method is most economical of audio power?

(A) Screen.
(B) Grid.
(C) Cathode.
(D) Suppressor grid.
(E) Plate.

ANSWER: (B)

8. In an average AM amateur transmitter using plate modulation, the output of the microphone is fed into a:

(A) Speech amplifier.
(B) Modulator stage.
(C) Driver amplifier.
(D) RF amplifier plate circuit.
(E) RF amplifier grid circuit.

ANSWER: (A)

9. In the above transmitter, the output of the speech amplifier is introduced into the:

(A) Grid of the modulator tube.
(B) Plate of the final amplifier.
(C) Grid of the final amplifier.
(D) Grid of the driver stage.
(E) Plate of the modulator tube.

ANSWER: (D)

10. If a transmitter were grid modulated rather than plate modulated, the output of what stage of the modulation system would feed directly into the RF amplifier tube?

(A) Speech amplifier.
(B) Driver.
(C) Modulator.
(D) None.
(E) Final.

ANSWER: (A)

11. What is the maximum legal percentage of modulation at which an amateur transmitter can be operated?

(A) 100%.
(B) 85%
(C) 95%
(D) 50%.
(E) 75%.

ANSWER: (A)

12. What undesirable effects are caused by overmodulation?

(A) Increased plate current and off-frequency operation.
(B) Loss of grid drive and reduced plate current.

(C) Plate saturation and an over-all loss of audio power.
(D) Off-frequency operation and reduced RF output.
(E) Signal distortion and splatter (generation of spurious side-bands).

ANSWER: (E)

There are many relatively minor points in connection with modulation systems, not involving the system as a whole but rather specific parts thereof, on which you are likely to be questioned. Since they are all rather vital to proper operation of the overall system employed, it is essential that you have at least a speaking acquaintance with them. In the following paragraphs we will, therefore, provide you with brief descriptions of these points which should enable you to handle any questions that may be presented in your examination on these subjects.

GRID BIAS

You will frequently run across this term in connection with audio or radio frequency vacuum tube circuits. Boiled down to its simplest form, bias voltage is a relatively low negative DC voltage applied to the grid of a tube. This voltage serves to control the plate and grid current of the tube, and a very small change in bias voltage will produce a far greater change in plate current than will adjustment of the plate voltage. Tube manuals almost invariably specify the amount of rated grid *current* for which the tube was designed. The voltage requirements vary so widely, dependent on the use of the tube, that this is seldom specified. In ham radio construction manuals and articles having to do with devices using vacuum tubes, the negative grid voltage is generally specified. This will be at a value which will produce the desired grid *current*. Grid current should not exceed the manufacturers' rating, as by so doing the tube can easily be damaged. Most manufactured transmitters make provision for determining the grid *current*, either by using a separate grid meter (milliammeter) built into the panel or by use of a dual scale meter which can be switched to read either grid or plate current. The grid current reading is an accurate means of determining the proper amount of "drive" to the tube from the preceding stage. Almost invariably the instruction manuals accompanying factory-made transmitters and kits will specify the amount of grid current required to properly excite the following stage. They also include rather firm caution against exceeding the maximum rated current.

Bias voltage is obtained from any available DC source in the transmitter. If taken from the negative high voltage DC supply, a "grid leak" or resistor of proper value dependent on circuit characteristics serves to drop the voltage to the required value. A separate, low-voltage DC source is sometimes built into a transmitter or its power supply to furnish the low voltage and small current requirements for grid bias. Sometimes dry cell batteries, often termed "C" batteries, are used for this purpose, and their negative terminal is connected to the control grid of the tube.

AMPLIFIER CLASSES

Another rather common term which will confront you frequently is "Class," as applied to both RF and AF amplifiers. You will read and hear about "Class A," "Class B," "Class AB," and "Class C" amplifiers. This is a subject that could be carried into great detail; however, we will attempt to give you merely a most elementary description which will be adequate for your examination, with the suggestion that you pursue further study of this subject (as well as grid bias in the foregoing paragraph). Briefly, then, a Class A amplifier can be used as either a voltage or power amplifier. The grid bias and AC voltages applied to the grid of a tube connected for Class A operation are such that plate current flows through the tube at all times (with or without an applied signal). The audio power output of a Class A amplifier is much less than that available from a Class B amplifier, but the former has low distortion characteristics.

An amplifier designed for Class B operation is biased approximately to the cutoff value (the point where plate current is practically zero) and conducts when a signal is applied to the grid, but for only about one half of each cycle. Some manufacturers offer what are known as zero-bias tubes for Class B operation, and, as their name implies, they require no form of bias.

A combination of both the Class A and Class B amplifiers, known as Class "AB," takes advantage of the desirable characteristics of both types, having the low distortion capability of the class A amplifier as well as the higher power output and efficiency of Class B.

In Class C operation, the grid is biased beyond the cutoff point of the tube, and the plate current is zero with no signal applied. When an AC voltage is introduced at the grid, plate current flows for appreciably less than one half of each cycle. The Class C amplifier enjoys its greatest popularity as the final amplifier in radio frequency applications. Its plate efficiency is high, averaging around 70%.

Classification of these amplifiers is somewhat general, in that they resemble each other in many respects. Into which class they fall is dependent upon a number of factors, such as the type of tubes used, amount of bias voltage, plate voltages and currents, and similar factors. A study of the schematic diagrams of the various classes, where such diagrams indicate voltage and current values, tube types, minor wiring differences, and minor component variations, will be of most value in understanding the distinction between these types. At the same time, a study of the material in publications devoted to detailed discussion of amplifiers will, of course, add greatly to the information provided here.

Shall we try several questions now before we leave this chapter?

1. Grid bias, in its broad sense, refers to:

    (A) A positive high voltage applied to the grid of a vacuum tube.
    (B) A positive low voltage applied to the grid of a vacuum tube.
    (C) No voltage to the grid of a vacuum tube.
    (D) A relatively low negative voltage applied to the grid of a vacuum tube.
    (E) A negative high voltage applied to the grid of a vacuum tube.

ANSWER: (D)

2. The terms "Class A, B, AB and C" are applied to:

    (A) Audio amplifiers.
    (B) RF amplifiers.
    (C) RF oscillators.
    (D) Audio oscillators.
    (E) Both RF and audio amplifiers.

ANSWER: (E)

3. A Class C amplifier is most commonly used as a:

    (A) Speech amplifier.
    (B) Driver stage.
    (C) Modulator.
    (D) RF power amplifier.
    (E) Frequency modulator.

ANSWER: (D)

CHAPTER 8

BASIC ELECTRONIC THEORY

REACTANCE

Although previous chapters have dwelt considerably on the subject of basic electricity, you will likely be questioned on some miscellaneous items concerning the theoretical aspects of electronic circuits as applied to radio transmitters. For example, let's take a brief look at the term "reactance." This is a phenomenon most commonly related to capacity and inductance. Capacitive reactance, for example, is the opposition a capacitor offers to AC. Expressed in ohms, its value decreases as either the frequency or capacity or both are increased. Likewise, a decrease in either or both the frequency and capacity will increase the capacitive reactance. If (as when alternating current is applied to a capacitor), the *current* rises to its peak and completes its cycles somewhat ahead of the accompanying voltage rise, the current is said to "lead" the voltage—or, to put it another way; the voltage "lags" the current. On the other hand, if the voltage cycle *precedes* the current cycle, the voltage is said to be "leading" and the current "lagging." The *amount* of lag or lead is referred to in terms of degrees, assuming a complete cycle to be 360°. Therefore, if one or the other were leading by one-fourth of a cycle, it would be said to be leading by 90°. With a capacitor, the voltage across it lags the current by 90°. The amount of *opposition* presented by the capacitor can be determined by the following formula:

$$X_C = \frac{1}{2\pi fC}$$

where,

X_C is the unknown quantity of capacitive reactance expressed in ohms,

f represents the frequency of the charging voltage in megacycles,
C is the capacity of the capacitor in microfarads,
π equals 3.1416.

Capacitive reactance is not the only reactance we will be concerned with. The reactance presented by an *inductance* and known as "inductive reactance" also enters into electronic calculations. In a sense, inductive reactance is the direct opposite of capacitive reactance. Its opposition to the current flow increases or decreases as the frequency does. The voltage across a coil leads the current through it by 90°. The formula for determining the inductive reactance of a coil is:

$$X_L = 2\pi fL$$

where,
X_L is the unknown value of inductive reactance,
f is the frequency in cycles per second,
L is the inductance in henrys,
π is 3.1416.

When a coil and a capacitor are connected together (either in series or in parallel), a tuned circuit is formed. Briefly, when the values of inductance and capacitance are such that the reactance of one cancels that of the other, the circuit is at resonance. At this point we could needlessly become involved in theory about which you will not be questioned on your test. Suffice it to say that the resonant frequency of a tuned circuit is dependent on the values of capacitance and inductance, and that a decrease in the value of either will cause the circuit to resonate at a higher frequency. For example, if the coil of a tuned circuit develops shorted turns, the inductance will be reduced and subsequently the circuit will resonate at a higher frequency.

There is of course more to reactance and to current lag and lead than we need go into at this time. The basic principles set down here, along with memorization of the two formulas, should adequately cover any questions you might be asked on your FCC examination. You can always delve further into these subjects if you so desire.

CIRCUIT "Q"

Circuit "Q" is an expression you will frequently encounter in electronics and one you should be familiar with because there may be one or more questions about this subject on your examination. The fact that Q is the seventeenth letter of the alphabet has no relationship to its use in connection with electronic circuits. In this latter usage it is sometimes referred to as "figure of merit." The "Q" is a symbol associated with the electrical quality of a coil. It is expressed as the ratio between the inductive reactance of the coil and its resistance. Mainly we will be concerned with the "Q" of coils connected in resonant load circuits such as those of final amplifiers, antenna tuners, etc. We have already seen that reactance is a variable which depends not only on frequency, but on the value of the capacitor or the electrical size of an inductor as well. When an inductor and capacitor form a resonant circuit feeding a load such as an antenna or the following stage in a transmitter, it should have a low L/C ratio (low L and high C, where L represents inductance and C, capacity) in order to achieve a fairly high "Q". And why a high "Q"? In the first place, regardless of its mechanical makeup, any coil will have *some* resistance. Perhaps your volt-ohm milliammeter combination won't show it . . . it is infinitesimal, but still very real. Likewise, the opposition which a capacitor presents to the flow of radio-frequency energy is bound to include a minute amount of resistance. There will also be slight resistance losses through the coil supports, plus those losses identified with the capacitor. The greater the resistance, the greater the heat loss. You can't feel it with the naked hand; nevertheless, the resistance is there and so is the heat.

To boil it all down, the more heat loss caused by resistance, the lower the circuit "Q." Thus, the higher the "Q," the greater the efficiency as a consequence of less resistance loss. Moreover, the higher the "Q" (within reason), the greater the circuit selectivity and subsequently the less chance of your passing undesirable harmonic frequencies into your neighbor's TV or radio set! Let's break it off here with a few questions.

1. Reactance in a component represents:

   (A) Opposition to AC voltage and current in the circuit.
   (B) Generation of a voltage of opposite polarity.
   (C) Reduction in the current-handling capability of the circuit.
   (D) Multiplication of the voltage in the circuit.
   (E) Increased efficiency in the circuit.

   ANSWER: (A)

2. Reactance involving opposition to AC in an inductance coil is known as:

   (A) Capacitive reactance.
   (B) Voltage reactance.
   (C) Circuit "Q".
   (D) Current reactance.
   (E) Inductive reactance.

   ANSWER: (E)

3. What does the *Q* factor indicate with reference to RF circuits?
   - (A) The seventeenth letter of the alphabet.
   - (B) The relative efficiency of the circuit.
   - (C) The resistance present in an inductance coil.
   - (D) The losses present in a capacitor.
   - (E) The power-handling capability of the circuit.

ANSWER: (B)

4. Which produces greatest efficiency in RF circuits?
   - (A) Low "Q".
   - (B) No "Q".
   - (C) High reactance.
   - (D) High "Q".
   - (E) Low reactance.

ANSWER: (D)

5. In designing a high- "Q" circuit, do we want:
   - (A) High resistance?
   - (B) Heat dissipation?
   - (C) Small capacity?
   - (D) Low L/C ratio?
   - (E) High L/C ratio?

ANSWER: (D)

6. The voltage across a coil:
   - (A) Lags the current flowing through it by 90°.
   - (B) Leads the current flowing through it by 90°.
   - (C) Is equal to the current flowing through it.
   - (D) Is zero when current is flowing through it.
   - (E) Lags the current flowing through it by 180°.

ANSWER: (B)

7. The voltage across a capacitor:
   - (A) Leads the applied current by 90°.
   - (B) Is equal to the applied current.
   - (C) Leads the applied current by 180°.
   - (D) Lags the applied current by 90°.
   - (E) Is Zero when current is applied.

ANSWER: (D)

8. Better selectivity and suppression of undesired harmonics is obtained when a circuit has:
   - (A) More inductive than capacitive reactance.
   - (B) More capacitive than inductive reactance.
   - (C) A high "Q" factor.
   - (D) No "Q" factor.
   - (E) A low "Q" factor.

ANSWER: (C)

9. If shorted turns develop in a coil, the inductance will:
   - (A) Increase.
   - (B) Decrease.
   - (C) Remain the same.
   - (D) Double.
   - (E) Be reduced to zero.

ANSWER: (B)

10. Reducing the inductance of a tuned circuit will cause its resonant frequency to:
    - (A) Decrease.
    - (B) Increase.
    - (C) Remain unchanged.
    - (D) Double.
    - (E) Vary above and below its normal value.

ANSWER: (B)

TUNED CIRCUITS

As we mentioned previously, a tuned circuit comprises a capacitor and a coil. This combination can be connected either in series (Fig. 8-1A) or in parallel (Fig. 8-1B). It might be more correct to say that a tuned circuit consists of a capacity and an inductance, since physical components are not always involved. For example, in dealing with radio-frequency signals you may find a resonant circuit referred to, but see only a coil. This inductance may combine with stray capacitance between leads or with the interelectrode capacitance of a vacuum tube to form the resonant circuit. We will not elaborate on this any further, but will confine our discussion to tuned circuits comprising physical components.

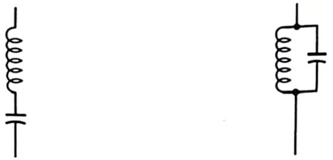

(A) Series. *(B) Parallel.*

Fig. 8-1. Tuned circuits.

Fig. 8-2 shows three tuned circuits and the methods of changing the resonant frequency of each. In Fig. 8-2A the circuit is tuned by varying the capacitance, while in Fig. 8-2B the inductance is varied. The resonant frequency of the circuit in Fig. 8-2C can be changed by varying either the inductance or capacitance.

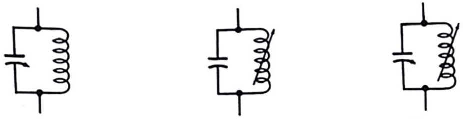

(A) Variable capacitance. *(B) Variable inductance.* *(C) Variable capacitance and inductance.*

Fig. 8-2 Methods of changing the resonant frequency of a tuned circuit.

Most amateur-radio transmitters employ either a fixed or an adjustable inductance and a continuously variable capacitor so that resonance may be established in the circuits at the desired frequency. By an adjustable inductance we merely mean that the coil or coils can be changed in the number of turns included in the circuit. Modern transmitters have a rotary switch which, by proper circuitry, selects a proper tap on a coil (Fig. 8-3) to provide the correct number of turns for the desired frequency. Popular practice favors the adjustable (not continuously variable) coil and the continuously variable capacitor. Selection of a predetermined number of inductance turns, plus proper adjustment of the variable capacitor, enables the desired frequency of oscillation and radiation to be chosen. At the same time, a reasonable balance is maintained between capacity and inductance so that an acceptably high "Q" will be achieved and a relatively efficient output thereby created.

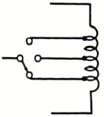


Fig. 8-3 Various amounts of inductance can be obtained by means of a tapped coil and a selector switch.

SKIN EFFECT

When we say conductors, we are speaking of any metallic object which will conduct electricity. This includes not only the conventional wire which is thought of whenever the word "conductor" is used, but *anything* else metallic as well.

Any conductor of electricity is capable of carrying electric current, but just how much current it can safely carry is determined by its physical size. With low-frequency voltages, the larger the cross-sectional area, the more current can be handled. If a wire is too small, it will become hot because of its resistance (opposition which it offers to the flow of current through it). Increasing the cross-sectional area of the wire will decrease the resistance; likewise, decreasing the area increases the resistance.

Radio-frequency currents act quite differently from low-frequency currents. Now the circumference of the conductor becomes important. Instead of flowing equally through the entire cross-sectional area of the wire, radio-frequency currents tend to flow along the surface. This is known as skin effect.

It seems as though radio-frequency currents simply can't spare the time to penetrate to the inner core of the wire or other metallic substance they are using for transportation. So they satisfy themselves by traveling only along the *surface!* Because of this skin effect, RF currents don't need a lot of material to comprise a conducting channel. This explains why hollow conductive tubing is often used in RF circuits, particularly at the higher power classification. Such tubing doesn't *need* a core; all that the radio-frequency current requires is sufficient circumference. That's why "heavy wire" is used in the tank inductance (heavy is relative; the wire really isn't very big); however, if you want to figure diameters, the wire does provide a great deal of *surface* for conduction and that's what we want for radio-frequency currents. Now for a few more questions.

1. Radio-frequency current flowing through a conductor is confined to:
   (A) The core of the wire or other conducting medium.
   (B) Only the device which originates it.
   (C) The radiating system.
   (D) The surface of the conducting material.
   (E) The radio power-supply source.

ANSWER: (D)

2. Direct current and alternating current at commercial frequencies uses, for conductivity:
   (A) All the area of the conducting material.
   (B) Only the surface of the conducting medium.
   (C) Partial area of the conducting medium.
   (D) Only the core of the conducting medium.
   (E) None of the conducting medium.

ANSWER: (A)

3. The phenomenon which causes electricity at radio frequencies to flow only on the surface of a conductor is called:
   (A) Conductivity.
   (B) Resistance.
   (C) Oscillation.
   (D) Skin effect.
   (E) Resonance.

ANSWER: (D)

OHM'S LAW

Some of the questions and problems on the FCC test will no doubt involve the use of the Ohm's-law formula and its derivatives. This fundamental electrical law expresses the relationship between current, voltage, and resistance (designated I, E, and R, respectively). Using it you can compute the value of the third quantity if only two are known. The formula is expressed as follows:

For DC forms:

$E = I \times R$

$R = E \div I$

$I = E \div R$

where,

E is the voltage,
R is the resistance,
I is the current.

For AC forms:

$E = I \times Z$

$Z = E \div I$

$I = E \div Z$

where,

E is the voltage,

Z is the impedance,

I is the current.

As an example, say you want to determine the value of a resistor. If you know the voltage drop across and the current through the resistor, you can compute its value by dividing the voltage by the current. (Before computing, however, the current must be converted into amperes if you have not done so already.)

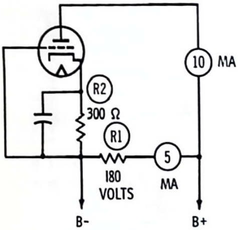


Fig. 8-4. Ohm's-law formula can be used with this circuit to compute plate and bias voltages as well as the value of resistor R1.

You will likely be given a basic vacuum-tube circuit like the one in Fig. 8-4 and be asked to use Ohm's law to compute the plate voltage, grid bias, and voltage drop across one of the resistors. The value of either R1 or R2 will probably be given and you'll be asked to determine the value of the other. Work a few problems using Ohm's law, until you are thoroughly familiar with it.

SERIES- AND PARALLEL-CONNECTED COMPONENTS

Resistors

You will no doubt be questioned about such things as "what happens to the over-all value when two capacitors are connected in parallel?" or "how are two resistors connected to increase resistance?"

First of all, remember that when two or more resistors of equal values are connected in series, their resistances add. For example, two, 1,000-ohm resistors in series equal 2,000 ohms. The opposite occurs when they are connected in parallel; the resistance is reduced to essentially half that of a single resistor—

500 ohms. The formula for computing the value of resistors in parallel is:

$$R_{\text{total}} = \cfrac{1}{\cfrac{1}{R_1} + \cfrac{1}{R_2} + \cfrac{1}{R_3} \dots}$$

For only two resistors the formula reads:

$$R_{\text{total}} = \frac{R_1 \quad R_2}{R_1 + R_2}$$

Capacitors

Capacitors act just the opposite from resistors. That is, when two capacitors of equal value are connected in series, their over-all value is half that of one capacitor: in other words, two 40-mfd capacitors in series equal 20 mfd. Converseley, capacitors connected in parallel add and in this example would have an over-all value of 80 mfd. The formula for computing capacitors in series is as follows:

$$C_{\text{total}} = \cfrac{1}{\cfrac{1}{C_1} + \cfrac{1}{C_2} + \cfrac{1}{C_3} \dots}$$

For only two capacitors in series:

$$C_{\text{total}} = \frac{C_1 \quad C_2}{C_1 + C_2}$$

For capacitors in parallel:

$$C_{\text{total}} = C_1 + C_2 + C_3 \dots$$

It's interesting to note that although the value of two capacitors (of equal value) connected in *series* is only half that of a single capacitor, the voltage rating of the combination is twice as much. If a defective filter capacitor in the plate supply of a transmitter is rated 4 mfd at 1,000 volts, it can safely be replaced by two 8-mfd, 500-volt capacitors connected in series. In fact, this is common practice in amateur radio, since two capacitors with lower voltage ratings are usually less costly than a single unit with a high voltage rating.

Inductors

You may or may not be questioned on inductors in series and parallel, but the formulas will be included here, to be on the safe side. The formula for inductors in series is:

$$L_{\text{total}} = L_1 + L_2 + L_3 \dots$$

For inductors in parallel, the formula is:

$$L_{\text{total}} = \cfrac{1}{\cfrac{1}{L_1} + \cfrac{1}{L_2} + \cfrac{1}{L_3} \dots}$$

For only two inductors in parallel:

$$L_{total} = \frac{L_1 L_2}{L_1 + L_2}$$

While on the discussion of formulas, we'll include the one for determining the wavelength of radio waves, even though it is somewhat out of place. You may be asked about it on the FCC exam, but even if not it will be helpful later in determining the proper length of antenna elements, for example. To find the wave length of a radio wave, use the following formula:

$$\lambda = \frac{300,000,000}{f}$$

where,

λ is the wavelength in meters (1 meter equals 39.37 inches),
f is the frequency in cycles.

Now, how about some questions?

1. The over-all resistance of two 500-ohm resistors connected in parallel is:
   (A) 1,000 ohms.
   (B) 2,000 ohms.
   (C) 500 ohms.
   (D) 250 ohms.
   (E) 100 ohms.

   ANSWER: (D)

2. The over-all resistance of two 3,000-ohm resistors connected in series equals:
   (A) 6,000 ohms.
   (B) 1,200 ohms.
   (C) 1,500 ohms.
   (D) 3,000 ohms.
   (E) 9,000 ohms.

   ANSWER: (A)

3. When two capacitors of equal value are connected in series, the total capacitance is:
   (A) Doubled.
   (B) Tripled.
   (C) One-half the value of a single capacitor.
   (D) Zero.
   (E) One and one-half the value of a single capacitor.

   ANSWER: (C)

4. When two capacitors of equal value are connected in parallel the total capacitance is:
   (A) Half the value of one capacitor.
   (B) Triple the value of one capacitor.
   (C) Same value as one capacitor.
   (D) Twice the value of both capacitors.
   (E) Twice the value of a single capacitor.

   ANSWER: (E)

VACUUM TUBES

Basically, all vacuum tubes are identical in that they consist of an enclosing sealed envelope of glass, metal and fairly recently, even ceramic, from which (except for certain types such as mercury-vapor rectifier tubes) all air, gas, and vapors have been exhausted, leaving an almost perfect vacuum. Although vacuum-tube envelopes vary widely in shape and size, they all contain two or more metallic elements, or electrodes, and have suitable connecting leads extended through airtight seals to the outer surface of the envelope to permit external connection.

For your FCC examination you will need to know a number of basic points about the vacuum tube. You will not be required to demonstrate a scientific knowledge of principles and theories, but only a basic understanding of the role which vacuum tubes play in amateur-radio transmission. This will require familiarity with the tubes commonly used in amateur practice, to the extent that you can demonstrate your ability to handle them in both radiotelegraph and radiotelephone operation to a degree which will assure legal operation of your transmitting equipment. Our discussion then will be based on this and will, we hope, give you a better conception of the vital place which vacuum tubes occupy in amateur operation.

The Diode

Logic seems to dictate that we start with the simplest tube in the vacuum-tube family—the diode. A diode, as the name implies (*di* meaning "two") contains only two elements, or electrodes—a cathode (electron-emitting element) and plate, or anode (electron-collecting element). In amateur practice the diode is most commonly used as a half-wave rectifier in a power-supply system or, in pairs, as a full-wave rectifier. Its two elements consist of a filament or heater and a single metallic plate. The filament type of tube uses a resistive wire (the filament is the cathode in this tube) which glows when the proper voltage is applied. The heater type of tube also has a filament, but it is enclosed within a small metallic envelope which also glows from the intense heat induced in it by the internal filament. The small enclosure for the filament is called a cathode and is electrically insulated from its enclosed filament. The cathode then replaces the filament as one of the two active elements within the tube envelope, its filament (referred to as the heater) having nothing to do with the tube action but merely serving as a means to heat the cathode.

A filament, or cathode, heated to an intense temperature—sufficient to make it glow—emits electrons. This action is called thermionic emission. Unless there is some place for the electrons to go, they will hover around the heated filament or cathode. Suppose though, that a potential is applied to the plate (anode).

If such a potential is *positive* with respect to the cathode (electron-emitting element), the electrons will be attracted to the plate. This action can be compared to magnetic attraction. Think of electrons as minute particles of magnetic matter which, if under the influence of a magnetic field, are instantly attracted to the magnetic source. That, in effect, is exactly what occurs when voltage is applied to the plate, or anode, of a vacuum tube. One dissimilarity exists; electrons are constantly being generated by the thermionic action of a heated filament or cathode, whereas metal particles being used to demonstrate magnetic attraction must constantly be replenished by some artificial mechanical means in order to form a continuous path between their source and the point of magnetic attraction.

The path formed by the electrons passing between the cathode and anode is continuous as long as the plate remains more positive than the cathode. This current flow is relatively unrestricted. What little resistance *is* present is commonly referred to as internal tube resistance and, being small (although it does create some voltage drop) is of little consequence inasmuch as it is taken into consideration by design engineers. Lack of positive voltage at the anode interrupts the conducting path and the tube, in effect, becomes an open circuit.

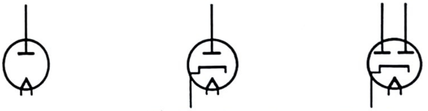

(A) Filament type.
(B) Indirectly-heated cathode.
(C) Full-wave.

Fig. 8-5. The diode vacuum tube.

Fig. 8-5 shows the schematic symbols representing three types of diode vacuum tubes you will encounter in amateur radio. In Fig. 8-5A is shown the filament type and, in B, one using an indirectly-heated cathode. The diode in Fig. 8-5C has two plates and a common cathode and is usually employed as a full-wave rectifier in power supplies. As we progress in our study of vacuum tubes, we will find that many of the basic principles of the diode carry over to other tube types. For example, cathodes and anodes appear in *all* tube types and perform the same functions in each. That, then, can be said to make the diode the *basic* vacuum tube. As we progress it will be evident that, broadly speaking, it is merely the addition of more elements within the tube envelope which constitutes the difference between the diode and other tube types. Whether the multielement tubes which we will describe are fitted with a filament or with an indirectly heated cathode makes no difference whatsoever. Whether the anodes are round, square, rectangular, or what is also immaterial, as long as they are metallic. We might mention that the material of which the filaments and/or cathodes are made is also of small consequence except that some materials are capable of producing much greater electron emission in their thermionic action than others. Thoriated tungsten is one, but even greater efficiency can be obtained by using oxide-coated filaments or cathodes; both will be found throughout the huge vacuum-tube family.

The Triode

The triode we are about to consider is a *three*-element tube, *tri* meaning "three." The third element, called the control grid, is located between the cathode and plate (Fig. 8-6). It is this element that makes amplification possible. Applying an AC voltage to the grid, for example, varies the normal plate current flowing between the cathode and plate accordingly. However the relatively small voltage at the grid makes a much larger change in plate current, thereby producing a much stronger duplicate of the grid signal in the plate circuit.

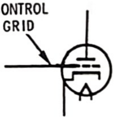


Fig. 8-6. The triode.

To break this explanation down further, the control grid controls the flow of electrons between the cathode and plate. With positive voltage on the plate and no voltage on the grid, the tube will conduct current between the cathode and plate in the normal manner. However, a negative voltage applied to the grid will tend to repel the electrons leaving the cathode (electrons are negatively charged particles). Just how much the plate current is reduced will depend on how negative the grid is. On the other hand, were the grid to be made *positive*, it would greatly *accelerate* the flow of electrons toward the anode, thereby providing a *lower* resistive conducting path between cathode and anode. The grid is much closer to the cathode and therefore has more control than the plate over electrons leaving the cathode. Obviously, then, the greater the *negative* voltage on the grid, the greater its repelling action. Conversely, the greater the positive voltage on the grid, the greater the acceleration given the electrons flowing from cathode to anode. A small change in grid voltage serves to change the value of plate current to the same extent as a large change in plate voltage, thereby making amplification possible. Since it is not desired to attract electrons to the grid, its mechanical structure is in the form of a mesh, screen, or helix through which the electrons can pass with a minimum of obstruction enroute to the plate.

Tetrodes

A tetrode, and the pentode to be discussed next, bring us into the screen-grid family of vacuum tubes. A tetrode has the same cathode, anode, and grid as the triode just discussed, *plus* another element in the form of a second grid (Fig. 8-7). Rather than acting as a control grid like our first grid, the second grid acts as a "neutralizing screen." Introducing such a grid between the control grid and the plate forms somewhat of an electrostatic shield which effectively neutralizes the capacitive effect between these elements. A smaller positive voltage than that on the plate is applied to the screen grid which, like the control grid, is constructed of an open mesh through which electrons can readily pass. Being positively charged, the screen grid also tends to accelerate the flow of electrons passing through the control grid enroute to the plate. These electrons travel so fast that they pass right through the wire mesh of the screen grid even though it is relatively positive. They are then attracted to and picked up by the anode, as though the screen grid were not present.

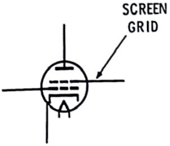


Fig. 8-7. The tetrode.

Pentodes

The addition of the screen grid and its effect on reducing the interelectrode capacitance between the grid and plate is fine. However, the positive charge on the screen causes the electrons to travel toward the plate with such speed that another problem is introduced. High velocity electrons often strike the anode with enough force to knock additional electrons out of it. These, in turn, strike other elements and may even be attracted to them. This action, known as "secondary emission," is undesirable because all electrons are needed at the plate rather than around the interior of the envelope, where they do more harm than good.

In a triode, the negative control grid handles this situation very well, repelling the negatively charged electrons back to the anode.

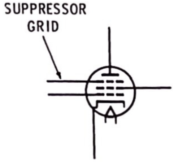


Fig. 8-8. The pentode.

This can again be likened to magnetic phenomena, whereby like charges repel and unlike charges attract. When we get into the screen-grid type of tube such as tetrodes, the positive charge on the screen serves to assist the electrons knocked out of the plate in scurrying away from it. To overcome this effect, a *third* grid is inserted into the tube envelope, between the screen grid and the anode (Fig. 8-8). Known as the suppressor grid, this third element tends to offset or cancel out the attracting effect offered the secondary electrons by the positive charge on the screen grid. The suppressor grid is kept more negative than the plate and screen. As a result, while the negatively charged electrons may travel from the plate toward the screen, the influence of the negative charge on the suppressor grids repels them back toward the plate and within reach of the attracting force. This time they stay put!

Beam Power Tubes

A number of otherwise conventional tubes of the screen-grid type are popular under the group classification of "beam power tubes." While they all follow the same general pattern as the other screen-grid types discussed, their design and physical construction are such that their internal electron flow is directed in a concentrated beam toward the anode. In other words, rather than having the electrons scampering helter-skelter throughout the tube envelope in their effort to reach the anode, they are directed toward the anode in a beamed effect which assures no side excursions. By so doing, their power sensitivity is increased and they will handle larger plate currents with relatively lower voltages, to attain the same wattage. An additional feature is their ability to produce large power outputs with much lower values of grid driving power. Such tubes are now found in more and more amateur equipment. While commercially available in several types, the beam power tetrode is by far the most common in the amateur field.

One rating you'll be concerned with in regard to the power-handling capabilities of a tube is the plate dissipation. This rating, given in watts, is the maximum safe-heat radiating capabilities of the plate or anode. You'll find a number of other tube ratings and specifications listed in tube manuals. Whenever in doubt about the safe operating conditions of a tube, consult such a manual. It wouldn't be a bad idea to familiarize yourself with some of these ratings, since you may be asked about one or two of them on your FCC exam, and it always pays to be prepared for any eventuality.

In addition to the tube types mentioned in this chapter, you will also encounter many variations, such as multi-purpose tubes which may include one or more diodes and a pentode within a single envelope, or a dual triode, dual pentode, triode-pentode, etc. Your examination will probably be concerned only with the basic types, however. You can carry your study of vacuum tubes much further if you desire, but this covers the basic aspects and is all you'll need to know for your exam.

Now, how about some questions?

1. A diode vacuum tube has:

(A) One grid.
(B) Three grids.
(C) No grid.
(D) Two grids.
(E) Four grids.

ANSWER: (C)

2. A vacuum tube containing a cathode, an anode, and three grids, is known as a:

(A) Tetrode.
(B) Pentode.
(C) Diode.
(D) Triode.
(E) No such tube.

ANSWER: (B)

3. A tetrode vacuum tube has:

(A) Two grids.
(B) No grid.
(C) One grid.
(D) Three grids.
(E) Five grids.

ANSWER: (A)

4. A triode is similar to a diode vacuum tube except that:

(A) The plate is much smaller.
(B) It contains a grid.
(C) It cannot handle as much current.
(D) It contains two grids.
(E) It contains no grids.

ANSWER: (B)

5. The second grid of a tetrode tube serves to:

(A) Double the control capacity of the first grid.
(B) Neutralize the control effect of the first grid.
(C) Decrease the grid current.
(D) Increase the grid current.
(E) Neutralize the interelement capacity between the first grid and the plate.

ANSWER: (E)

6. The third grid of a pentode tube is known as the:

(A) Screen grid.
(B) Control grid.
(C) Auxiliary grid.
(D) Suppressor grid.
(E) Neutralization grid.

ANSWER: (D)

7. The rating that expresses the maximum safe-heat dissipating capabilities of the plate of a vacuum tube is known as:

(A) Plate resistance.
(B) Plate dissipation.
(C) Plate capacitance.
(D) Plate conductance.
(E) Plate current.

ANSWER: (B)

8. The element or electrode in a diode tube which emits electrons by thermionic action is known as the:

(A) Anode or plate.
(B) Cathode.
(C) Envelope.
(D) Base assembly.
(E) Terminal connection.

ANSWER: (B)

9. The action whereby high-velocity electrons flowing to the plate strike it with enough force to knock electrons out of it is known as:

(A) Plate dissipation.
(B) Secondary emission.
(C) Plate resistance.
(D) Plate conduction.
(E) Plate power input.

ANSWER: (B)

That just about does it. If you've absorbed all the information contained herein, you're ready to move on to the next chapter, where we'll discuss US radio laws and FCC rules and regulations in connection with amateur radio.

CHAPTER 9

FCC RULES AND REGULATIONS

At first thought, you might consider a chapter on this subject superfluous, particularly since you may have already taken a Novice examination wherein you were required to be familiar with certain rules and regulations. Just the same, there are three very good reasons for including this chapter. First, there is a good chance that even though you have once passed such an examination, a number of the rules are now somewhat obscure to you. For example, if you have been a good, law-abiding ham, which we presume you have, you have had no occasion to become entangled with penalties. However, can you recall from memory the maximum penalty applicable for violation of the FCC rules and regulations? How about the penalty which *may* be assessed if you willfully interfere with other radio communications? These and many other questions, together with their answers, appear at the end of this chapter to refresh your memory.

The second reason is that not everyone reading this book has taken an FCC exam prior to this time; and third, certain *additional* rules and regulations that did not apply to Novice operation may be included in the General exam.

POWER INPUT

This is a simple point but it does have a catch! You say, "Oh, I know all about that; as a Novice I was restricted to 75 watts, but now I can use a full 'gallon' (kilowatt)." This is not exactly true. The fine print in the rules and regulations says that you may use a full 1000 watts input if you have an accurate means of measuring it; if not, your power restriction is 900 watts! Did you know that? And there is room for argument over what constitutes an accurate means of measuring your power input. If you actually know the exact amount of plate voltage on your final amplifier tube under key-down conditions (or carrier 'on'), and your gear is supplied with an accurate milliammeter, or ammeter as the case may be, the FCC may accept the multiple; but should they have occasion to question your power input, one of their inspectors is completely within his right to measure accurately your input power with his precision instruments. And if you're out of bounds—well, it can and probably will be a bit uncomfortable for you and can very well result in one or more of the prescribed penalties!

A sound piece of advice here is to recommend strongly that you keep your maximum input power to about 850 to 900 watts. If you are equipped with accurately calibrated instruments and are adept in their use, you can handle a kilowatt with rather firm assurance that you'll be legal. On the other hand, if you are a new-comer to the high-power field through recent acquisition of a General, Conditional or Technician license, take it easy; let your power input grow with your experience! What's more, there is a very good chance that you'll have fewer TV complaints from neighbors if you hold it down.

The FCC regulations further stipulate that only the amount of power input needed to maintain the desired communications may be used. For example, an operator would be way off base in using a kilowatt to talk with another ham on the other side of town when effective communication could be accomplished with only a fraction of such power.

Another regulation that must be adhered to concerns portable operation away from the fixed station location specified on your license. When you propose to operate portable or mobile ham equipment away from that fixed point or outside of your call area for a period exceeding 48 hours, you must give advance notice to the FCC engineer in charge of the call area in which such operation is intended. The following information should be included in the notice:

1. Your name (as licensee of the fixed station).
2. Your fixed station call sign.
3. The authorized address of your fixed station.
4. Your complete itinerary as a portable station away from the fixed location for more than 48 hours; tell the FCC where you will be and when you will be there, with specific dates insofar as you can determine them in advance. Notify them *again* if this schedule and itinerary changes.

5. An address or (preferably) a telephone number at which you may be reached during each period of temporary (portable) operation.
6. If you are also equipped to operate mobile from such temporary locations, include the license number of your automobile, aircraft, or water vehicle, or the equivalent registration number.

There are many regulations affecting amateur operation, and you should become familiar with them. You'll find that such things as using profane, indecent, or obscene language on the air, operation without a license, giving unassigned call letters, and superfluous, false, or deceptive communications are strictly prohibited. You may be asked about these on your examination.

FCC AND THE HAM

As in enforcement of any law, there must be enforcement officers. FCC law-enforcement personnel are not policemen constantly on the look-out for the criminal element. They are highly skilled engineers, trained to detect violations of the U.S. radio laws and the rules and regulations of the Commission. Many of the violations which they uncover through their very efficient system of twenty-four-hour radio monitor stations are completely innocent (that is, without criminal intent). Johnny Jones down the street, during his early Novice operation we'll say, radiated some horrible key clicks which come within the category of spurious radiation and caused unnecessary interference, even though not willful. Maybe one or two of Johnny's friends have mentioned this to him over the air; perhaps he's a little doubtful of what they really said—his initial code ability is rather shaky. If that is what he *thought* they said, he should, of course, have checked his own gear to confirm or deny it. If he doesn't go over his equipment, it might be quite a jolt for Johnny when he receives a formal little pink slip in the mail from the FCC, calling his attention to these spurious radiations.

The FCC operates in a most courteous and gentlemanly but firm manner; and in addition to the tremendous license burden placed on this agency, it is woefully understaffed. It is pretty evident that United States radio amateurs should appreciate FCC efforts and co-operate whole-heartily, as by far the greater majority do. Ham radio has its few "Peck's Bad Boys" (and unfortunately a few who are even worse), but the over-all picture is a most creditable showing for the ham.

PENALTIES

Perhaps the one thing the average ham overlooks is the distinction between "Radio Laws of the United States" and "Rules and Regulations of the Federal Communications Commission." The "laws" as such are just that, and they are the result of the passage of legislation by the Congress of the United States, which, after ratification by the President, become governing laws. In such legislation, Congress specifically details the requirements, sets up the penalties, and makes whatever other provisions may be necessary to assure recognition of the laws and compliance therewith by all concerned. For example, while the FCC is a Federal commission whose members are appointed by the President, the law enacted by the Congress specifies how they are supposed to perform. Among other provisions, they are authorized to establish certain rules and regulations (not laws which, as previously stated, is a function of the Congress). Therefore, in establishing such rules and regulations, the FCC sets up its own schedule of penalties and—remember this well—the maximum penalty which the Commission has established for violation of its rules and regulations, is a fine of $500 for each day on which the violation occurs! In addition, they may also suspend an operator's license and revoke his station license! Might sound a bit on the tough side, but remember that is the *maximum* penalty which, as a Commission, they can assess. On the other hand, violation of Federal law as enacted by the Congress carries the possibility of a fine up to a maximum of $10,000, two years imprisonment in a Federal prison (either or *both*), and this can be in addition to the maximum FCC penalties mentioned previously. This makes it rather obvious that while amateur radio is a pleasurable hobby, it most certainly has its serious angles and it is easily possible to become involved to a somewhat greater extent than handing the municipal traffic court judge $2 for a parking violation!

Don't for a minute let this scare you. You should have no occasion to tangle with the Commission any more than you would a judge for assault with a deadly weapon. As an amateur radio operator with a legally licensed station, play the game, show sportsmanship, and have fun!

Now for some questions. Here we go.

1. The legal limit for power input to a ham transmitter whose owner holds a Technician, Conditional, or General license and is provided with accurate measuring means is:

(A) 900 watts.
(B) 1000 watts.
(C) 500 watts.
(D) 75 watts.
(E) 100 watts.

ANSWER: (B)

2. If accurate measuring equipment is not on hand, the legal limit for power input to an amateur transmitter is:

(A) 1000 watts.
(B) 100 watts.
(C) 75 watts.
(D) 900 watts.
(E) 500 watts.

ANSWER: (D)

3. The maximum penalty for violation of an FCC rule or regulation is:

(A) $500 per day for each day of such violation, plus suspension of operator license and revocation of station license.
(B) $10,000 fine and/or imprisonment up to two years in addition to above penalty.
(C) No penalty.
(D) A citation from FCC.
(E) Loss of amateur status.

ANSWER: (A)

4. The maximum penalty for violation of a *U.S. radio law* is:

(A) $500 per day for each day of such violation, plus suspension of operator license and revocation of station license.
(B) $10,000 fine and/or imprisonment for two years in addition to penalties in (A).
(C) No penalty.
(D) Five years imprisonment.
(E) $20,000 fine.

ANSWER: (B)

5. The FCC is primarily a:

(A) Law enforcing agency concerned only with communication laws of the United States, FCC rules and regulations and international aspects.
(B) An agency to see that *all* Federal laws, rules and regulations are observed.
(C) A communications licensing agency.
(D) A register of licensed amateur operators.
(E) A directory agency listing all amateur radio operators.

ANSWER: (A)

6. An amateur station may broadcast music and similar entertainment:

(A) Only for testing purposes.
(B) On any frequency above 240 mc.
(C) At will.
(D) Never.
(E) Only in the 3.5 mc band.

ANSWER: (D)

7. A United States amateur radio operator (and station owner, if such applies) is subject to:

(A) Only FCC rules and regulations.
(B) Only radio laws as enacted by the Congress of the U.S.
(C) International radio agreements between the U.S. and foreign countries, only.

(D) A combination of A, B, and C above.
(E) No laws, treaties, or regulations.

ANSWER: (D)

8. The legal U.S. agency authorized to administer United States and International Radio Laws as well as rules and regulations of their own is:

(A) The Federal Bureau of Investigation.
(B) The Internal Revenue Service.
(C) The Federal Airways Commission.
(D) The Federal Communications Commission.
(E) The U.S. Postal Service.

ANSWER: (D)

9. An amateur radio operator may willfully interfere with communications between other stations if:

(A) Such operation is above the frequencies of 144 mc.
(B) Never.
(C) He considers such other operation inconsequential.
(D) He uses continuous-wave telegraph.
(E) The communication with which he interferes is not of a "distress" nature.

ANSWER: (B)

10. An amateur station may operate during distress or emergency communications only if:

(A) He is attempting to work a distant country.
(B) He is already in social communication with another station.
(C) He is attempting to establish contact with a distant station.
(D) He is aiding in the distress or emergency situation at the request of an authorized agency or individual.
(E) He is testing his equipment performance.

ANSWER: (D)

11. What radio traffic has priority over all other communications?

(A) Distress calls and distress communications.
(B) Communications between FCC officials.
(C) Communications between U.S. and foreign operators.
(D) Traffic regarding government matters.
(E) Communications that have been in progress in excess of thirty minutes.

ANSWER: (A)

12. An amateur transmitter must have an adequately filtered DC plate power supply for operation on all frequencies below:

(A) 14 mc.
(B) 220 mc.
(C) 144 mc.
(D) 50 mc.
(E) 3.5 mc.

ANSWER: (C)

13. A state of emergency affecting amateur operation becomes effective:

(A) 10 hours after announcement by an FCC official.
(B) Anytime within 24 hours after notification.
(C) Within one hour after notification by the FCC.

(D) When so ordered by the FCC.
(E) At no time.

ANSWER: (D)

14. The FCC must be given prior notification if portable or mobile operation is intended outside the assigned call area for a period exceeding:

(A) 24 Hrs.
(B) 48 Hrs.
(C) 12 Hrs.
(D) 16 Hrs.
(E) 6 Hrs.

ANSWER: (B)

CHAPTER 10

AMATEUR OPERATING PRACTICES

As we stated previously, no one book can include everything you need to know on any subject. You should therefore supplement your study of this book by generous reference to other types of material connected with ham-radio operation. Add to this, attendance at your local radio club meetings if you are fortunate enough to reside in an area where they are held. Talk face-to-face with other hams, participate in group activities such as "field days," and subscribe to one or more ham periodicals to keep abreast of the latest developments. The more active you are in any hobby, the more you will get out of it. Amateur radio is no different in this respect.

It may or may not have occurred to you that ham radio could be classed as a sport as well. When ham radio is thought of in that category, the natural assumption is that it will present a challenge. And it does! In golf, tennis, bowling . . . you name it . . . no one wants to be the "end man." People constantly strive to lead their opponents . . . to beat their own scores. If your interest is mainly in CW telegraphy, you don't want to lag even a couple of words a minute behind the other ham; actually, you'd like to be able to send or receive a few words per minute faster than him. And you can if you conscientiously devote your spare time to the constant practice it will take.

As a General-class ham, your operating procedures on the air are going to change somewhat. For example, as a novice, working only with other novices, you have taken your operating cues from them. In CW operation the initial call, almost without exception, will run something like this: "KN7XYZ . . . KN7XYZ . . . KN7XYZ . . ." and on and on for maybe ten or fifteen calls, followed by "DE . . . DE . . . DE" three or more times and then by your own call sign, ten, twelve . . . maybe fifteen! Do that when you have a General-class license and many hams will leave you cold; they simply won't wait it out because you have most certainly identified yourself as a recent graduate from the beginners' ranks. There is no hard and fast CW procedure for returning a call. One method that has worked quite well involves giving the call of the station initiating the CQ three times, DE (from) once, and your call letters three times. Repeat this sequence, but give the call letters only twice, and a third time giving each only once. This "tapering" procedure cuts the calling time shorter but results in probably as many or more replies as the long, drawn-out methods. If a ham misses your call the first time, he will probably tune around and pick it up on the second round. If he still isn't sure, he should get it from your last, single set of call signs. Placing the shoe on the other foot, if radiotelephone is your major interest, your goal is (or most certainly should be!) to be just that much better an operator than the next ham. And what constitutes a "better" operator, in either classification? Not only code ability for the CW man, but also snappy operating procedure for the one using phone. Although both are vital, remember that true sportsmanship comes first.

The writer received a letter not long ago, from Robert Weinstein, K4KXR, of Miami Beach, Florida. Bob, whose company manufactures a popular line of commercial antennas, has been an active ham for many years. He is completely familiar with amateur operating practices on all bands and by all modes. His letter contributed a number of thoughts which are most certainly worthy of consideration, not only by the "old-timer," but also by those of you who are just now entering the General. Conditional, or Technician class of ham radio. If Bob had written his thoughts as a magazine article, it could well have been entitled, "Food for Thought." The writer doesn't feel that he can improve on the way Bob puts it, so let's quote the next few paragraphs verbatim from Bob's letter:

"Many years ago, when automobiles were a novelty, every motorist was an adventurer; a sportsman who greeted other motorists with enthusiasm. They stopped to meet strangers, exchange ideas and hints, perhaps strike up the prelude to life-long friendships. Every motorist then experimented with every part of his car. He had to know not only how to change a tire, but to patch a tube, repair a carburetor, even strain his gasoline to eliminate impurities. With the passage of years, a new breed of motorist appeared. He bought all of his automotive equipment ready-made and never bothered to learn what made it tick. He could barely change a tire, had no particular interest in motoring other than how fast he could go and, unfortunately, how many people he probably missed killing or injuring! Today, every other motorist is a potential enemy; the adventure and thrill are gone . . . driving is no longer a pleasure but a hard grind.

"Much of this can be compared to present-day ham radio. The early days belonged to the experimenter . . . the thrill seeker, . . . the builders; men and boys (and some girls even entered the picture in early years) with basic knowledge or a thirst for such. As ham radio grew, we found that it was slowly but surely following in its own way, the established path of pioneer automobiling, and its progress has been somewhat akin to present-day motoring. Listening on the air today can be *fun*, if you and other hams contribute to this end. Deliberate QRM, bad manners, snarls . . . even actual verbal fights (unfortunately we sometimes hear them!) do *not* contribute to ham sportsmanship. A ham (and a lot of other people!) should be courteous, kind, and helpful. A *good* ham does *not* deliberately interfere with QSO's between other stations. Neither does he deliberately stea the other fellow's contacts. He responds to a plaintive, weak, maybe somewhat shaky CQ if only to perhaps give a signal report. He is generous with his time in aiding other hams.

"The good ham helps amateur radio in general by helping others to become interested in this glorious hobby; in assisting in clearing up interference with neighborhood TV reception, and eliminating key clicks and other spurious radiations by other stations. He gladly gives information to prospective hams, and helps the novice in clearing points which may puzzle him. He contributes to public service by being a member of a local Civil Defense communication group or, after a bit of experience, becomes a member of the Military Amateur Radio System (MARS) who provide a most valuable service in maintaining a no-cost contact between families of servicemen who, by reason of military necessity, must be separated, often by many thousands of miles. Local Red Cross organizations also offer a splendid opportunity for public service on the part of the amateur radio operator.

Editorial note: the HOOSIER AMATEUR WOMENS' KLUB . . . HAWK . . ., an organization of female radio amateurs of the State of Indiana, and the INDIANA COUNCIL OF RADIO CLUBS . . . incorporating in its membership all bona-fide radio clubs in the state, should be particularly commended for the line they carry in each issue and on many pages of their individual monthly club papers; "HAWK'S EYE VIEW" and the "BISON," respectively. It reads, "Amateur radio exists because of the service it renders."

"Radio amateurs should by all means contribute to the art by learning as much as possible about the various phases of ham radio. They should experiment with new developments in the particular branch of ham radio in which they are interested; invest in publications and magazine subscriptions in this field to the extent which they can afford. Try various circuits, a variety of antennas . . . any 'gimmick' which might appear to increase their knowledge of their chosen hobby. It is entirely possible that such experimentation could contribute mightily to progress of the art. Remember, basically all that de Forest did was to insert a 'hairpin' in the 'pickle bottle' of Dr. Fleming and 'wireless' (now 'radio') was revolutionized!

"Join a local club and be *active;* join the American Radio Relay League (the International, non-profit organization of radio amateurs) and, by your voice which may be heard on vital issues through your vote as a member, express your individual opinion. When any public law, or change in existing radio laws and/or regulations and rules, is proposed, have your say by your vote through the only organization which is, as their slogan reads, '. . . of, by and for, the amateur'.

"Don't start false rumors; don't discuss race, or religion or allied subjects over the air; in other words, don't engage in controversial subjects which could lead to emnity. Don't be too critical . . . don't be too dissatisfied . . . don't 'knock' everything; in short, be a 'gentleman' (or lady) as may be applicable."

The above quotes from Bob are, in this writer's opinion, just about the best summing up of what constitutes a good amateur that we could use. Add to them the provisions of the "RADIO AMATEUR'S CODE" which appears in the forefront of each edition of the Radio Amateur's Handbook of the American Radio Relay League, observe the provisions of each to the letter, and you'll be a good amateur. Now let's drop back into a little discussion of a few minor items which will, we hope, assist you in your examination questions.

As a General, Conditional, or Technician class licensee, you will find much more expanded usage of "Q" signals. Therefore, review them since you may be asked the meaning of several on your FCC examination. If you want to know the location of the other station with whom you had established contact, you would ask his "QTH." What is the readability of my signals . . . for this you use "QRK?" If he is being bothered by other stations or by some man-made interference such as neon signs, defective electrical appliances, etc., he will tell you "QRM," the formal meaning of which is "I am being interfered with." If the growls and grumbles of nature (atmospheric disturbances)—casually referred to as "static"—are making your reception difficult and perhaps his also, you use the signal "QRN." There are many such "Q" signals and they prove to be a distinct asset in handling radio communication. You will find that their use is widespread among the General-class stations, because they convey a complete phrase in a few letters. You hear a station sending "QST" in place of calling some individual station. You may already know (if not, you'll find out in short order as a General-class ham) that this means a general message of interest to all amateurs is about to follow. It therefore will be a distinct advantage to you to know all the commonly used "Q" signals. There are many of them; however, a good proportion are used in commercial radio services, and these you need not be concerned with. Take, for example, "QTE" which, if followed by a question mark means, "What is my true bearing from your station?" It is applicable mainly to ships and aircraft . . . you will seldom if ever use it as a ham. Learning *all* the "Q" signals is not a must, however, insofar as your Federal examination for a General-class license is concerned. You no doubt *will* be asked a few questions having to do with "Q" signals applicable to amateur operation, many of which you probably are already familiar with. It would be needless to include a list of the commonly used "Q" signals at this point, since such listings already appear in many current publications. We can add to this only a recommendation that you familiarize yourself with those signals listed, for you will not be a General-class ham for long before you'll be hearing and using most if not all of them. We will, however, give you one tip. While the "Q" signals appear in most publications as a single statement, bear in mind that if you follow a "Q" signal with a question mark, the statement to which it refers becomes a question. To clarify this, let's take one of the more common "Q" signals as an example. You want to exchange QSL cards with a fellow but he's not yet listed in the call book. You have to know his mailing address, just as he must know yours, before you can exchange cards. So you ask him, "QTH?" Followed by the question mark, this "Q" signal means, "What is your location?" In answering, the other fellow will send the signal "QTH" (*without* a question mark), preceding the actual address to indicate that it is a reply to a "Q"-signal query.

The same applies to use of the "R-S-T" signals, which you will also find in numerous ham publications. You want to know how your signal sounds at the other end of your communication link . . . so does the ham at *that* end. So, using the chart, you tell him perhaps, "RST478." To him, taking the figures from the chart, his "readability" is R-4; ". . . readable with practically no difficulty." Next, you give him his signal strength; in this case "S-7' . . . moderately strong signals, and the last designation of your report is his "tone" as you see it – T-8. This means that he has a ". . . good DC note; just a trace of ripple . . ." If he had a really ". . . pure DC note . . . ," you would have given him a "T" figure of 9. In radiotelephone operation the same system is employed except that you use only the RS designations; the T is dropped since it applies only to CW. A perfect phone report, for example, would be a 5-9. An entire book could be written on the subject of good operating practice alone, but since you have become interested in amateur radio as a hobby you will no doubt absorb the correct procedures and normal operating practice. As your experience grows, you will find ham radio more and more absorbing.

SAFETY

The subject of operating practice would not be complete without some precautions on general safety that apply to radio equipment as well as those who operate it. Chances are you will receive some questions on your examination dealing with safety measures.

If you formerly held a Novice ticket you have undoubtedly been exposed to the dangers of the high voltage employed in transmitters. But for those who are planning to take the higher grade license examination but have had no previous experience with such equipment, some words of caution are in order.

The voltages encountered in Novice equipment are dangerous enough, let alone those present in the high-powered units which you will be permitted to use as a Technician-, Conditional-, or General-class licensee. Such voltages can be lethal unless treated with respect. On the other hand they can serve their intended purpose and yet be perfectly safe.

Manufacturers have gone as far as possible in designing transmitters that are safe. The rest is up to you. Make it a point to *never* work on radio equipment while it is connected to the voltage source. This cannot be overemphasized.

Some manufacturers equip their transmitters with an interlock switch on the rear panel or door, permitting the line voltage to be disconnected from the unit automatically when the transmitter is opened.

(Should a person accidentally come in contact with a high voltage and become unconscious, use extreme care in removing him from the voltage source. The correct procedure is to open the main switch and thereby remove the voltage first. Then pull the person away from the equipment. Never touch any part of the person's body until the voltage has been shut off. If you do, you won't be helping him or yourself. This may seem a little bleak but you may well be asked about this on the exam.)

Since your radio equipment will probably represent a pretty healthy investment, you should also consider safety precautions in regard to it. Your chief concern here will be lightning protection. Besides grounding the antenna mast or tower, a device known as an antenna grounding switch should be used. When the rig is not in use, this switch should be in the ground position to help protect the equipment should lightning strike the antenna.

Now lets cover some questions on the subject of operating practices.

1. "Q" signals serve the radio services as:

   (A) A three-letter method of asking or answering a phrase.
   (B) Calling for help in case of distress.
   (C) Establishing contact with other stations.
   (D) Conveying Civil Defense information.
   (E) Notification that a broadcast transmission of information to all radio services follows.

   ANSWER: (A)

2. The signal "QTH?" means:

   (A) I am located at . . . . (followed by address).
   (B) Your compass bearing from me is . . . . . . degrees.
   (C) I am being interfered with.
   (D) What is your location?
   (E) Static interference is preventing good reception.

   ANSWER: (D)

3. "QRM" has the meaning:

   (A) I am being interfered with.
   (B) I am subject to static interference.
   (C) Your signals are good.
   (D) A general broadcast to all stations will follow.
   (E) I have no message for you.

   ANSWER: (A)

4. Write at least ten of the "Q" signals with their meanings. We won't help you on this one; you pick them from existing charts and memorize all you can.

5. The "RST" method of reporting signal strength interprets "R" as:

   (A) Signal strength.
   (B) Signal tone.
   (C) Signal readability.
   (D) Illegal note.
   (E) Reception impossible.

   ANSWER: (C)

6. What device is used to protect radio equipment from damage due to atmospheric electrical charges entering the antenna system?

(A) A lightning rod placed on the roof.
(B) A power-line filter.
(C) An antenna grounding switch.
(D) An SWR meter connected in series with the antenna lead.
(E) An isolation transformer at the antenna input connector.

ANSWER: (C)

7. What is the primary purpose of an interlock switch on the rear panel or door of a transmitter?

(A) To help keep the door or panel tightly closed.
(B) To prevent accidental shock after transmitter is opened.
(C) To prevent the radiation of RF while adjustments are being made.
(D) To reduce the drain on the power supply.
(E) To keep unauthorized persons from tampering.

ANSWER: (B)

8. The first step in removing an unconscious person from contact with a high-voltage source is to:

(A) Pull the main switch to remove the voltage.
(B) Check for a heartbeat.
(C) Notify the nearest relative.
(D) Summon a doctor.
(E) Determine how the accident occurred.

ANSWER: (A)

If you have conscientiously studied the foregoing pages and have avidly read and digested other literature on ham radio, you should make the grade with little trouble. When you're ready is up to you and is dependent on several factors. First, perhaps we should list, is your *interest!* Closely behind will be a demonstration of such interest by your devotion to study. The increased code knowledge which you must have to become a General-class licensee simply won't come easy. You're going to have to work for it. Likewise, the wider understanding of electrical and radio fundamentals which you will require for any of the three classes of licenses is again a matter which will require *you* to contribute to through broader study of the subjects.

You want to become a member of the world-wide fraternity of radio hams of the General class. You want to shake the shackles to which you were subjected as a Novice licensee . . . you want the additional privileges which the General class offers, but to acquire them, you must *earn* them. And that is how it should be; most of the good things in this world (and ham radio is *good*) are *not* dropped into a lap, nor are they inherited by the "silver spoon" route. You and *only* you must demonstrate that you have what it takes to secure recognition as a Technician, Conditional, or General class, U.S. radio amateur. Can you meet the challenge? Sure you can . . . get in there and *dig!*

APPENDIX

FCC FIELD AND EXAMINATION OFFICES

Mailing addresses for Commission Field Offices are listed below. Street addresses can be found in local directories under "United States Government."

FIELD ENGINEERING OFFICES

Address all communications to Engineer in Charge, FCC

Alabama, Mobile 36602
Alaska, Anchorage 99501 (P.O. Box 644)
California, Los Angeles 90014
California, San Diego 92101
California, San Francisco 94111
California, San Pedro 90731
Colorado, Denver 80202
District of Columbia, Washington 20554
Florida, Miami 33130
Florida, Tampa 33602
Georgia, Atlanta 30303
Georgia, Savannah 31402 (P.O. Box 77)
Hawaii, Honolulu 96808
Illinois, Chicago 60604
Louisiana, New Orleans 70130
Maryland, Baltimore 21202
Massachusetts, Boston 02109
Michigan, Detroit 48226
Minnesota, St. Paul 55102
Missouri, Kansas City 64106
New York, Buffalo 14203
New York, New York 10014

Oregon, Portland 97205
Pennsylvania, Philadelphia 19106
Puerto Rico, San Juan 00903 (P.O. Box 2987)
Texas, Beaumont 77701
Texas, Dallas 75202
Texas, Houston 77002
Virginia, Norfolk 23510
Washington, Seattle 98174

COMMON CARRIER FIELD OFFICES

Address all communications to Chief, Common Carrier Field Office, FCC

Missouri, St. Louis 63102
New York, New York 10007

EXAMINATION POINTS

Examinations for amateur radio operator licenses are conducted at the Commission's office in Washington, D.C., and at each field office of the Commission on the days designated by the Engineer in Charge of the office. Specific dates should be obtained from the Engineer in Charge of the nearest field office of the Commission.

Examinations are also given frequently, by appointment, at the Commission's offices at the following points:

Anchorage, Alaska.
Beaumont, Tex.
Gettysburg, Pa.
Mobile, Ala.
San Diego, Calif.
Savannah, Ga.
Tampa, Fla.

Examinations are also given at greater intervals at the places named below, which are visited for that purpose by Commission examiners from the field offices for such locations. For current schedules, exact time, place, and other details, inquiry should be addressed to the office conducting examinations at the chosen point.

QUARTERLY POINTS

Birmingham, Ala.
Charleston, W. Va.
Cincinnati, Ohio.
Cleveland, Ohio.
Columbus, Ohio.
Corpus Christi, Tex.
Davenport, Iowa.
Des Moines, Iowa.

Fort Wayne, Ind.
Fresno, Calif.
Grand Rapids, Mich.
Indianapolis, Ind.
Knoxville, Tenn.
Little Rock, Ark.
Louisville, Ky.
Memphis, Tenn.
Milwaukee, Wis.
Nashville, Tenn.
Oklahoma City, Okla.
Omaha, Nebr.
Phoenix, Ariz.
Pittsburgh, Pa.
St. Louis, Mo.
Salt Lake City, Utah.
San Antonio, Tex.
Schenectady, N.Y.
Sioux Falls, S. Dak.
Syracuse, N.Y.
Tulsa, Okla.
Williamsport, Pa.
Winston-Salem, N.C.

SEMIANNUAL

Albuquerque, N. Mex.
Boise, Idaho.
El Paso, Tex.
Fairbanks, Alaska.
Hartford, Conn.
Jackson, Miss.
Jacksonville, Fla.
Las Vegas, Nev.
Lubbock, Tex.
Portland, Maine.
Salem, Va.
Spokane, Wash.
Tucson, Ariz.
Wichita, Kans.
Wilmington, N.C.

ANNUAL

Bakersfield, Calif.
Bangor, Maine.
Billings, Mont.
Great Falls, Mont.
Hilo, Hawaii.
Jamestown, N. Dak.
Klamath Falls, Oreg.
Lihue, Hawaii.
Marquette, Mich.
Missoula, Mont.
Rapid City, S. Dak.
Wailuku, Hawaii.

Arrangements have also been made, including cooperation of other Federal agencies, for General Class examinations in outlying areas as follows:

Alaska: Alaska Communications System Stations.

Guam: District Communications Officer, United States Naval Station.

Hawaii: At not exceeding one point on any island, by the Engineer in Charge (Honolulu).

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GENERAL CLASS Amateur License HANDBOOK

SECOND EDITION

by Howard S. Pyle W7OE

Contrary to popular belief, an aspirant to the ranks of amateur radio is not required to begin with a Novice license. With proper guidance, anyone having a basic understanding of electronics, together with the ability to send and receive International Morse Code, can prepare for and pass the FCC examination for a higher-class license.

This book introduces the reader to the types of material on which the examinations for the Conditional-, Technician-, and General-Class licenses are based. It is designed to provide not only the additional information needed by the novice, but also the basic theory necessary for the newcomer to amateur radio.

Mr. Pyle begins by explaining the requirements for various grades of amateur-radio licenses. He then describes proven methods for learning the code and increasing your ability to use it. He also discusses transmitter circuits, progressing from oscillators to RF power amplifiers, followed by basic electronic theory, FCC regulations affecting amateur radio, and general operating practices. All of the latest changes introduced by the new incentive-licensing regulations are included in this book.

Questions of all types that you will receive on your FCC test are included throughout this book. The answers, plus explanations where needed are also given.

ABOUT THE AUTHOR

Mr. Pyle has been a ham for 60 years, starting as a lad in 1908. He was formerly an assistant radio inspector and an electronic engineer with the U.S. government. He is a senior member of the IEEE and past vice-director of the Northwestern Division of the ARRL. Now "retired" he frequently contributes to the various amateur radio publications, authors books, and still finds time to spend in his shack at Mercer Island, Washington, where his W70E is a familiar call to fellow hams. He is the author of three other Sams books: *abc's of Ham Radio*, *Advanced and Extra-Class Amateur License Handbook*, and *Building your Amateur Radio Novice Station*.

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